ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

COLLEGE OF ARCHITECTURE AND CIVIL ENGINEERING

Assessment of Road Maintenance Management Practices of Addis Ababa City Road Authority (AACRA)

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A Thesis submitted to college of Architecture and Civil Engineering, Addis Ababa Science and Technology University, for partial fulfillment of requirement of Master of Science in civil engineering.

(Road and Transport engineering)

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Addis Ababa, Ethiopia

Addis Ababa science and Technology University

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Addis Ababa Science and Technology University

College of Architecture and Civil Engineering

Plagiarism declaration

This thesis work is my original work, was not copied, has not been presented for degree in any other university, and all the source used have been duly acknowledged

Daniel Agidew Agegne

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March 2017

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First of all and for most, I thank my God for safeguarding me and for the helps He has been providing me. Thereafter, I am grateful to my advisor, Alemayehu Ambo (PhD) who has been teaching and closely advising me as well as sharing me his experience and skills throughout my study. I would like to thank Habtamu Melese(PhD) who has been teaching ,Advising and giving me support in hard times and throughout my study. I would also like to thank all key informants who took part in the interview to share their experiences and the staffs of AACRA and ORF for their support during the study period.

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LIST OF ACRONYMS

CI	Condition Index
AACRA	Addis Ababa City Road Authority
AASHTO	American Association of State Highway and Transport Officials
AC	Asphalt Concrete
ADB	Asian Development Bank
ASCE	American Society of Civil Engineers
CMMS	Computerized Road Maintenance Management System
DCP	Dynamic Cone Penetration
DFID	Department for International Development
DFR	Department of Federal Road
dTIMS	Deighton Total Infrastructure Management System.
DUR	Department of Urban Road
ERA	Ethiopian Roads Authority
ETB	Ethiopian Birr
FHWA	Federal Highway Agency
FWD	Falling Weight Deflectometer
GDP	Gross Domestic Product

GIS	Global Information System
GPR	Ground Penetrating Radar
GTZ	Gesellschaft für Technische Zusammenarbeit
HDM	Highway Development and Management system
HMA	Hot Mix Asphalt
ICBP	Interlocking Cement concrete Block Pavement
JICA	Japan International Cooperation Agency
NCHRP	National Corporative Highway Research Program
NDT	Nondestructive Tasting
NLS	Network Level System
OECD	Organization for Economic Co-operation and Development
OJT	on Job Training
ORF	Ethiopian Office of Road Fund
PBC	Performance Based Contracts
PBMCs	Performance Based Maintenance Contracting System
PCC	Plain Cement Concrete
PDS	Pavement Data System
PMS	Project Management System

RMMS	Road Maintenance Management System
TRL	Transport research laboratory
USA	United States of America
USD	United States Dollar
WRA	World Road Association

ABSTRACT

Road maintenance management (RMM) is a very important aspect for systematically and objectively determining pavement quality and programming of timely maintenance activities in response to adversely observed conditions. Road maintenance management is a significant challenge in many developing countries in the world. However, technology has been effectively used to solve some of these problems.

RMM is a serious concern in Ethiopia because Lack of proper maintenance leads to higher vehicle operating costs, increase in travel time and number of accidents, and reduce reliability and level of service of transport system.

Addis Ababa, the capital city of Ethiopia, suffers those problems due to lack of proper maintenance and management system. Despite various maintenance actions undertaken, the condition however, become worse due to poor maintenance practices.

The aim of this research is to study the current road maintenance management practices in Addis Ababa, identify problems/shortcomings that are currently faced and develop a computerized road maintenance management system that will improve the current maintenance challenges.

Questionnaire was used to elicit data on the current road maintenance management practices in Addis Ababa City Road Authority (AACRA) and on the challenges faced during maintenance and management practices. To develop a computerized road maintenance Management system, Microsoft Sequence Query Language 2014 (MS SQL 2014) server were used to develop a database and the interface design was developed using Visual Studio 2013.

The results show that maintenance management process: road inventory and condition surveys not properly carried out, no maintenance prioritization criteria, and not appropriate planned. The major challenges faced during implementation of road maintenance management are: inadequate funding, scarce database and traditional data collection system through visual inspection and inadequate training of manpower.

As a possible solutions to current weaknesses of road maintenance management system, a computerized road maintenance management system was developed which comprises of all stages of road maintenance cycle namely Road inventory, Road condition survey, Road prioritization and Road maintenance plan. Data were collected from four road section to validate the system and it

showed that the system effectively produce Road Inventory, Road Condition Survey, Road Prioritization and Road Maintenance plan reports.

The developed computerized Road Maintenance Management system was found efficient in number of ways for example: It reduce the amount of paper work, saves time, use standard criteria and clear guideline for road maintenance prioritization, reduce the amount of man power required for maintenance management, it can be used as useful decision tool and increase the management efficiency. It is hoped that the development of this Road Maintenance Management System will assist highway agencies to the improvement of Road Maintenance Management system of AACRA.

Key words: computerized Road maintenance management system, efficiency,

CHAPTER ONE

INTRODUCTION

1.1 Back ground of the study

Roads are among the most important public assets in many countries. Road improvements bring crucial benefits to road users through improved access to Hospitals, Schools, Markets and overall economic development to the nation. Better roads also provide; improved comfort, speed, and safety; and lower vehicle operating cost. Road transport is an essential factor in the economic growth of developing countries to achieve this continuity of road transport benefits and thus real assets need to be maintained in good condition. Without regular maintenance however, roads can rapidly fall in to disrepair, preventing realization of the longer term impacts of road improvement on development, such as increased agriculture production and growth in school enrollment.

Although the need for road maintenance is widely recognized, it is still not getting adequately done. Many countries spend 20-50% of what they should be spending on maintenance of their road network. There are many reasons for this, some of them are challenges of distinguishing maintenance from other type of road work, calculating how much maintenance work. On the other hand, analysis typically establish that the annual cost of maintaining road is a small fraction of initial investment cost, usually 2-3% of major paved road and 5-6% of unpaved rural roads. A well-established principle which drives the need for maintenance is that spending money now saves future cost, asset deterioration, so that the cost to restore the conditions increase. Numerous studies quantified this effect; for example, countries with low income economics typically under invest, yet spend 50% more on this network; per kilometer, than higher developed countries. The World Bank has shown that delayed in road maintenance expenditure in Africa increases the total operating costs by between two to three times than the saving in maintenance cost(world roadAssociation 2014) .

A recent analysis of 85 countries that allocated road maintenance funds showed that, spending United States dollars (USD) of 12 billion on preventive maintenance would have eliminated reconstruction costs of USD 40 billion. The results was that an average net costs of USD 330 million, are wasted on avoidable reconstruction in each country (A.Fitz 1996)

In Sub-Saharan Africa, USD 150 billion was spent in 3 decades for buildings roads. Maintenance was neglected and a third of that investment has now been lost. The result is that USD 50 billion of key national assets are gone. (A.Fitz 1996)

Ethiopia has a total of around Forty Five thousand kilometers of road to be maintained and is carrying out a maintenance work on an average of twenty thousand kilometers annually by the Federal Road Agency. Though the current status of the country towards maintenance of road is showing glimpse of development, there is still a lot of work to be done in order to improve the road network. (ERA, 2014)

In Ethiopia like many other countries, road maintenance was neglected and to overcome these problems a separate organization called the Road Fund office (ORF) was established in June 1998 mainly to finance road maintenance and road safety activities. For the last five years (1998-2002) the ORF has invested Ethiopian Birr (ETB) 1,868,000,000 for maintenance and among these, 65% were spent on Federal roads, 25% on regional roads and 10% on selected municipal roads. Of the municipal money, Addis Ababa the capital city of Ethiopia, shared 50%. Even though, the maintenance and management practice is poor and inadequate and this leads to high vehicle operating cost, lack of comfort, controlled speed, poor safety and travel time wastages and others.

This research aims to improve road maintenance management practices by assessing the current condition, identifying the weakness and proposing effective approaches to improve the road maintenance management system .The research will focus on investigation of current maintenance management practice, data analysis, output generation and findings and developing a computerized road maintenance management system for improving road maintenance management practice.

1.2Statement of problem

Road Maintenance Management System (RMMS) is a maintenance management process aimed at systematically and objectively determining pavement quality and programming maintenance actions in response to observed conditions, budgetary constraints and economic optimization (reduction of user costs, optimizing agency maintenance cost).Inefficiency and poor road maintenance management methods are among other reasons attributed to the poor conditions of roads in Addis Ababa .Despite the various maintenance measures ,the road condition are still poor and vehicle operating cost are increasing.

Routine, Periodic and Emergency Maintenance activities conducted by the Addis Ababa City Roads Authority (AACRA) plays its own role in improving the existing road condition .However, the current maintenance practice is not enough for providing smooth vehicular flows without congestion and with less accidents. Therefore, it is very important to assess the current road maintenance management practices in Addis Ababa and propose a better, and efficient Road maintenance management system .With understanding, the aim of this thesis work is to assess the current road maintenance management practices on Addis Ababa roads and to develop a computerized road maintenance management system to enhance the country's economic, social and environmental development.

1.3Research question

i) Are there any established road maintenance management system used to manage maintenance activities in AACRA?

ii) What is the road maintenance management system used in AACRA?

iii) Is the current road maintenance management system satisfactory to manage maintenance activities effectively?

iv) What are the challenges of the current road maintenance management practices?

v) What should be done to improve road maintenance management system in Addis Ababa?

1.4 Objectives

1.4.1 General objectives

The broad objective of the study is to study the current road maintenance management practices and develop computerized road maintenance management system in Addis Ababa with a view of standardizing the maintenance management practices and increasing efficiency.

1.4.2 Specific objectives

The specific objective of the study are:

i) To evaluate the current road maintenance management practices in Addis Ababa and identify problems/shortcoming that are currently faced;

ii) To develop a module for road maintenance management processes and

iii) To Develop and validate a computerized road maintenance management system for a developed model.

1.5 Scope and limitation of the study

The scope of this research for achieving the goals is focused on AACRA'S road maintenance management system with in Addis Ababa City Roads Authority. The Road Maintenance and the Road Asset Management departments are the main targets of this research.

In this research there were limitations encountered during the conduct of the research. The encountered limitations were: unavailability of adequate documented data and reluctance to fully cooperate in some instances**.**

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Globally, roads are the dominant transport assets, comprising millions of kilometers across the nations. Road infrastructure provide a fundamental foundation to the performance of all national economies, delivering a wide range of economic and social benefits. Roads are often the single largest publicly owned national asset and, it is road maintenance that controls the depreciation in value and determines the impact of the network on road users and society. Without proper maintenance, the high value of any road network can be quickly eroded and road users and society can experience significant adverse impact if a road network is in poor condition. Technical publications often cite the statistics that for every additional $ 1 a developing country spends on road maintenance, road users save $ 3(Heggie.G 1996) .

According to the World Road Association considering purely the values added by commercial transport services, road transport contributes 3 -5% of the Gross Domestic Product (GDP).however, this ignores a number of other considerations (input of fuel and transport Equipment's) which if taken in to account, the contribution of transport to GDP, would be 20-30% .Adequately maintaining road infrastructure is essential to preserve and enhance those benefits. Therefore, the importance of maintenance need to be recognized by decision makers, funded appropriately and should be well managed to ensure maximum value achieved. Poor management of road maintenance will result serious consequences on economic wellbeing of a nation (world road Association 2014).

The importance of addressing road maintenance is now properly well understood and is illustrated by the consequences of neglect. For example, the World Bank estimated that of the 85 countries receiving their assistance for roads, the cost of reconstruction has been three to four times the cost of the preventive maintenance that should have been undertaken earlier (A.Fitz 1996)

Yet, even small budgets for maintenance make difference with proper planning and the right priorities. The situation in many countries concerning the road condition is not only urgent, it is critical. It is important to know the costs involved in road maintenance and the costs of not maintaining the roads. The money which is saved in maintenance budget by maintaining the roads

is ultimately paid by the users and society. This is the invisible tax, and the total cost to the economy is huge (Heggie.G 1996).

In many countries, it is believed to be a political benefit in favor of investing money in building new roads. However, maintenance does not have the same status or does not give the same opportunity to stake holders or decision makers to present themselves to the public. Something has to be done with this situation. We as professional people have to sell the message that maintaining roads are decisive importance for a country (Levik 2014).

In fact, unplanned or poorly planned road maintenance ends up being more expensive than well planned and executed maintenance. So in order to provide a continuous and suitable road maintenance, efficient, effective and well established maintenance management scheme is extremely important**.**

2.2 Pavement Deterioration, Causes and Its Remedial Measures

2.2.1 General concept of pavement

The term pavement in highway design, can be defined as the total thickness of a pavement including surfacing, base, sub-base and base course ifany.it is hard crust constructed over the natural soil for purpose of providing stable and even surface for the veichle.it is therefore a structure consisting of superimposed layers of material above the natural soil subgrade, whose primary function is to distribute the applied vehicle load to the sub grade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance and low noise pollution.(Abubakar 2016).

Based on structural behavior and for design purpose, the road pavements generally classified as:

i) **Flexible pavement (Bituminous pavements):** Flexible pavements are constructed of several layers of natural granular material covered with one or more waterproof bituminous surface layers, and as the name imply, is considered to be flexible. A flexible pavement will flex (bend) under the load of a tyre. The objective with the design of a flexible pavement is to avoid the excessive flexing of any layer, failure to achieve this will result in the over stressing of a layer, which ultimately will cause the pavement to fail. In flexible pavements, the load distribution pattern changes from one layer to another, because the strength of each layer is different. The strongest material

(least flexible) is in the top layer and the weakest material (most flexible) is in the lowest Layer. The reason for this is that at the surface the wheel load is applied to a small area, the result is high stress levels, deeper down in the pavement, the wheel load is applied to larger area, and the result is lower stress levels thus enabling the use of weaker materials.

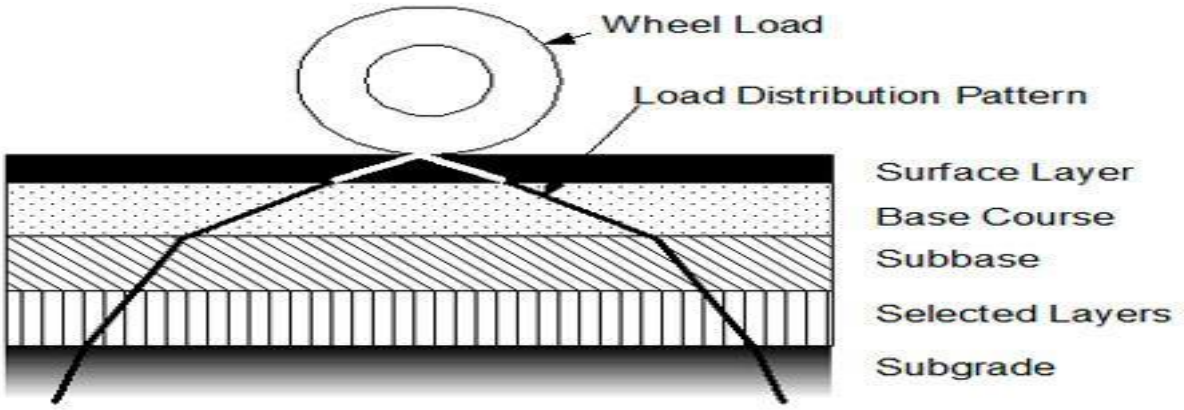


Figure 2.1 load distribution of flexible pavement

Source:(A.K.Gupta 2013)

ii) **Rigid (concrete) pavement:** Rigid pavements are composed of a PCC surface course. Such pavements are substantially "stiffer" than flexible pavements due to the high modulus of elasticity of thick material. Further, these pavements can have reinforcing steel, which is generally used to reduce or eliminate joints. The increased rigidity of concrete allows the concrete surface layer to bridge small weak areas in the supporting layer through what is known abeam action. This allows the placement of rigid pavements on relatively weak supporting layers, as long as the supporting layer material particles will not be carried away Bywater forced up by the pumping action of wheel loads.

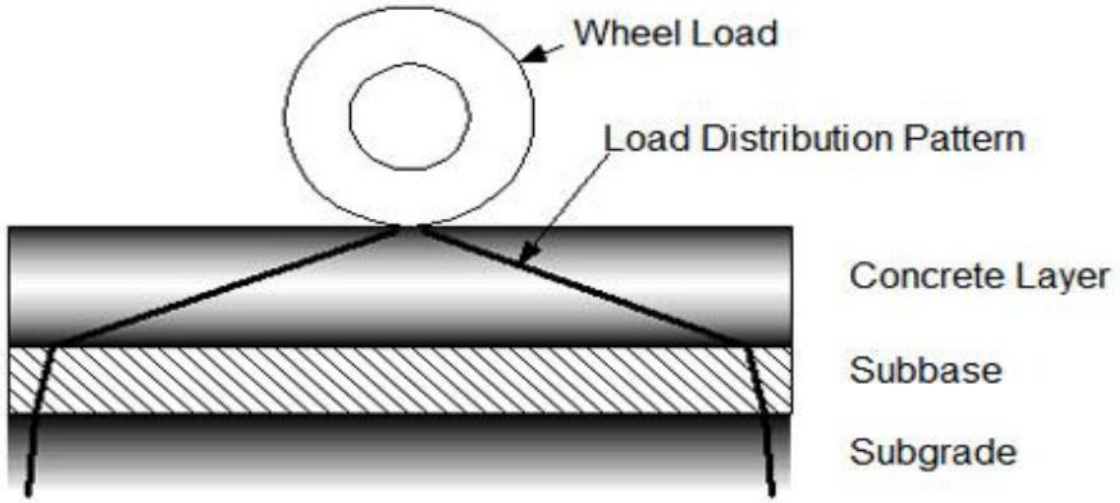


Figure 2.2 Load distribution of rigid pavement

Source:(A.K.Gupta 2013)

Other types of pavement structure include semi-rigid pavement or composite pavement and interlocking cement concrete block pavement (ICBP).however, these types of pavement are less common when compared to flexible and rigid pavement. Basic requirements of pavements are:

- It should be structurally sound enough to withstand the stress imposed on it.
- It should be sufficiently thick to distribute the loads and stresses to safe value on the subgrade soil.
- It should provide a reasonably hard wearing surface, so that the abrading action of wheels (pneumatic and iron –tire) does not damage the surface.
- It should be dust-proof so that traffic safety is not impaired by reducing the visibility.
- It should have a good riding quality and the surface should be impervious so that water does not get in to the lower layers of pavement and subgrade.
- The pavement should have a long life and cost of maintaining annually should be low (Abubakar 2016)

2.2.2 Factors influencing the performance of a pavement

According to (A.K.Gupta 2013) , factors affecting the performance of pavements are:

i) **Traffic:** Traffic is the most important factor influencing pavement performance. The performance of pavements is mostly influenced by the loading magnitude, configuration and the number of load repetitions by heavy vehicles. The damage caused per pass to a pavement by an axle is defined relative to the damage per pass of a standard axle load, which is defined as a 80 kN single axle load E80). Thus a pavement is designed to withstand certain number of standard axle load repetitions (E80's) that will result in a certain terminal condition of deterioration.

ii) **Moisture (water**): Moisture can significantly weaken the support strength of natural gravel materials, especially the subgrade. Moisture can enter the pavement structure through cracks and holes in the surface, laterally through the subgrade, and from the underlying water table through capillary action. The result of moisture ingress is the lubrication of particles, loss of particle interlock and subsequent particle displacement resulting in pavement failure.

iii) **Subgrade**: The subgrade is the underlying soil that supports the applied wheel loads. If the subgrades too weak to support the wheel loads, the pavement will flex excessively which ultimately causes the pavement to fail. If natural variations in the composition of the subgrade are not adequately addressed by the pavement design, significant differences in pavement performance will be experienced.

iv) Construction quality: Failure to obtain proper compaction, improper moisture conditions during construction, quality of materials, and accurate layer thickness (after compaction) all directly affect the performance of a pavement. These conditions stress the need for skilled staff, and the importance of good inspection and quality control procedures during construction.

v) Maintenance: Pavement performance depends on what, when, and how maintenance is performed. No matter how well the pavement is built, it will deteriorate over time based upon the mentioned factors.

According to World Bank 2008 road conditions can be expressed as: good, fair and poor

i) Good: paved road subsequently free of defects and requiring only routine maintenance. Unpaved roads needing only routine grading and spot repairs

ii) Fair: paved roads having significant defect and requiring resurfacing or strengthening .unpaved roads needing reshaping or resurfacing (re gravelling) and spot repair of drainage.

iii) Poor: paved roads with extensive defects and requiring immediate rehabilitation or reconstruction .unpaved roads needing reconstruction and major drainage works.

2.2.3 Road Deterioration and its cause

The developing countries have lost precious infrastructure worth billions of dollar through deterioration of roads .if their government do not much to prevent their roads they will lose billions more. Large road networks, built at great expense have been under maintained and more heavily used and abused than expected. If this continues, the deterioration of roads will increase rapidly as the old pavements crumble and the new ones outlive the initial period during which the effects of neglect are barely noticeable.(Abubakar 2016).

Pavement deterioration process starts directly after opening the road to traffic. This process starts very slowly so that it may not be noticeable, and over time it accelerates at faster rates. To ensure the risk of premature deterioration is minimized, it is necessary to use the best practice method in planning, design, construction and maintenance of the road. This can be achieved by examining pavements that have failed prematurely, with the focus being on determining the causes of failure so that it can be prevented in the future. The greater understanding of pavement failures that could be gained from detailed investigations could be valuable in reducing the costs associated with pavement failures in the future. In many cases the failure of pavement structure can be directly attributed to inadequate maintenance and ineffective evaluation programs. It is important to find out a method to minimize the maintenance cost under a limited budget.(.portien 2014) .

Pavement failure may be considered as structural, functional, or materials failure, or a combination of these factors. Structural failure is the loss of load carrying capability, where

the pavement is no longer able to absorb and transmit the wheel loading through the structure of the road without causing further deterioration. Functional failure is a broader term, which may indicate the loss of any function of the pavement such as skid resistance, structural capacity, and serviceability or passenger comfort. Materials failure occurs due to the disintegration or loss of material characteristics of any of the component materials.(.portien 2014, M.E.Zumrawi 2015).

Generally, bituminous pavement deterioration takes place due to combined action of traffic, weather change, drainage, environmental factors etc.

Flexible pavement generally deteriorates at very rapid rate when compared to rigid pavements due to the above factors. Flexible pavements continue deteriorate at slow rate even without the traffic movement of the surface due to climatic and environmental factors. Rate of deterioration of bituminous pavement increases rapidly when the water is retained in the void spaces of the bituminous pavement layers**.**

2.2.3.1 Types of Bituminous Pavement Deterioration

According to(Abubakar 2016), the common types of distress in bituminous pavements are classified in to the following four major groups:

2.2.3.1.1 Surface deformation

Surface deformation occurs usually due to failure or weakness in one of the layers of pavement due to traffic movement after construction. Common types of surface deformation includes the following:

i) **Corrugation:** it is a form of bituminous pavement distress which usually occur due to formation of regular and shallow undulation in the form of ripples or small corrugations of depth up to 25mm on the bituminous surface or across the road on some stretches. The probable causes of corrugation are include:

- Lack of stability in bituminous mix
- Excess binder content in the bituminous mix
- Excess proportion of fines in the mix
- Use of binder of low viscosity with respect to the temperature of the region

- Faulty Lying surface course

.The possible remedial measures for corrugation include scarifying the bituminous surfacing with corrugation and removing the surface along with top portion of the existing base course and re- compacting the material. After applying prime coat and tack coat another bituminous surface may be laid down using a mechanical paver.

ii) **Rutting**: this is the longitudinal deformation or depression of the pavement surface along the wheel path of heavy vehicles formed due to repeated applications of heavy load along the same wheel path resulting in cumulative non-recoverable or pavement deformation of the pavement layer including subgrade and one more of the pavement layer. The causes of rating could be:

- Inadequate stability of subgrade or sub-base or base course or few of the pavement layers
- Inadequate compaction of the subgrade or any of the pavement layers.
- Channelized movement of heavy wheel loads causing significant vertical stress on the subgrade
- Improper design and specification of bitumen mix
- Inadequate thickness of the pavement or weak pavement structure

The possible remedial measures procedures for this type of distress are:

- Cleaning the affected surface
- Application of tack coat and covering the ruts
- Filling the ruts using either a dense graded bituminous mix or open graded pre-mix followed by seal coat
- Compacting by roller
- Providing a thin bituminous resurfacing course to achieve good riding quality.

iii) **Shoving:** it is a form of plastic movement resulting in localized bulging of the pavement surface. Shoving can take a number of different forms such as upheaval, “wash boarding or ripples across the pavement surface, or even a crescent-shaped bulging. The causes of shoving includes:

- Lack of stability in the bituminous mix
- Too much binder content in the mix
- Use of rounded and smooth textured aggregate particles in the mix.
- Excess proportion of fines in the mix

The remedial measure for shoving is the removal of the materials to firm base and relaying a stable mix.

iv) **Shallow depressions**: are small localized bowel-shaped area that may include cracking. Depressions usually causes the roughness on the bituminous pavement surface and are hazardous to automobiles, and they also allow collection of water on the pavement surface. The cause of depression are the presence of inadequate compacted pocket or rather a localized consolidation or movement of the supporting layers beneath the surface course due to instability.

The possible remedial measure include filling with pre-mix materials, excavating and rebuilding the localized depressions, and reconstruction is required for extensive depressions.

v) **Settlement and upheaval**: settlement and upheaval occurs due to large deformations of the pavement surface caused by expansion of the supporting layers beneath the surface course or the subgrade. The causes of this distress includes: poor compaction of fills, poor drainage, and inadequate pavement. The possible remedies include: when the fill is weak, the defective fill should be excavated .when inadequate pavement is the cause, the pavement should be strengthened**.**

2.2.3.1.2 Cracking

Cracking is the presence of surface cracks significantly reduces the lie of bituminous pavements. This is because the surface cracks are one of the main contributors to the development of other different types of cracks in bituminous layers. They accelerate the development of cracking which would ultimately lead to early failure of the pavement. The common types of cracks include:

i) **Fatigue cracking**: it is a serious of longitudinal and interconnected cracks caused by the repeated applications of wheel loads. This type of cracking generally starts as short longitudinal cracks in the wheel path and progress to an alligator cracking pattern (interconnected cracks) .it happens due to repeated bending action of the hot mix

asphalt (HMA) when the load is applied, this generates tensile stress that eventually creates cracks at the bottom of the asphalt layer. Cracks gradually propagates to the top of the asphalt layer and later progress and interconnect. The possible causes include inadequate structure support which can be caused by a number of things. some of the most common :

- Decrease in pavement load support and characteristic
- Loss of base, sub-base or sub-grade support (e.g poor drainage or spring thaw resulting in less stiff base).
- Stripping on the bottom of the HMA (surface layer) (the stripped portion contributes little to the pavement strength, so effective HMA thickness decreases).
- Increase in loading (more than design load)
- Poor construction (e.g Inadequate compaction)

The remedial measures for a fatigue cracks generally includes:

- Removal of the cracked pavement area then digging out and replacing the area of poor subgrade and improving the drainage of that area if necessary.
- Patch over the repaired sub-grade.
- Alternatively, place the HMA overlay over the entire pavement surface. This overlay must be strong enough structurally to carry the anticipated loading because the underlying fatigue cracked pavement most likely contribute little or no strength.

ii) **Transverse cracking:** These are cracks perpendicular to the pavement centerline or lay down direction, they usually begins centerline and widen with age. If not properly sealed and maintained, multiple crack develop parallel to the initial crack. The possible causes of this type of cracking are:

- Shrinkage of the HMA surface due to low temperature or asphalt binder hardening; and
- Reflective crack caused by cracks beneath the surface layer.

The possible remedial strategies depend on severity extent of cracking.

Low severity cracking: (<1/2-inch-wide and infrequent cracks):

- Seal the cracks to prevent the entry of moisture in to the sub-grade through the cracks and further raveling of the cracked edges.

High severity cracking: (>1/2 inch wide and numerous cracks):

- Remove and replace the cracked pavement layer with overlay.

iii) **Longitudinal cracking:** These are cracks parallel to the pavement centerline or lay down direction, which may eventually lead to moisture infiltration, roughness, and may indicate the possible onset of alligator cracking and structural failure.

The possible causes include poor drainage, shoulder settlement, weak joints between adjoining spread of pavement layers or differential frost heave. The possible treatment depends on whether the pavement is structurally sound or unsound. Where the pavement is structurally sound, the cracks should be filled with low viscosity binder or slurry seal or fog seal depending on the width of the cracks. Unsound cracked pavements would need strengthening or rehabilitation treatment.

iv) **Edge cracking**: Edge cracks typically starts as crescent shapes at the edge of the pavement. They will expand from the edge until they begin to resemble alligator cracking. They may occur in a curbed section when subsurface water causes weakness in the pavement. This type of cracking result from lack of support of shoulders due to weak materials or excess moisture. Frost heave and inadequate pavement width also contributes towards formation of this type of distress. The remedial measures include filling the cracks at low severity. As the severity increases, patches and replacement of distress areas may be needed. In all the cases, the excessive moisture should be eliminated and the shoulders rebuild with good materials.

v) **Reflective cracking:** Reflective cracking has been traditionally thought to initiate at the bottom of the lower pavement layers and then propagate to the surface. Reflective cracks generally develop bituminous resurfacing or an overlay constructed over an existing cracked bituminous surface without resorting to appropriate measures. The most common causative agents of this type of cracking are due to joints and cracks in the pavement layer underneath. The possible treatment depends on whether the pavement is structurally sound or unsound. Where the pavement is structurally sound,

the cracks should be filled with low viscosity binder or slurry seal or fog seal, depending the width of the cracks. Unsound cracked pavements will need strengthening or rehabilitation treatment.

2.2.3.1.3 Disintegration

It is the progressive breaking up of the pavement into small, loose pieces is called disintegration. The two most common types of disintegration are:

i) **Potholes:** Potholes are small, bowl-shaped depressions in the pavement surface that penetrate all the way through the hot mix asphalt (HMA) layer down to the base course. They generally have a sharp edges and vertical sides near the top of the hole. Generally, potholes are the end result of fatigue cracking. As fatigue cracking becomes severe, the interconnected cracks creates small chunks of pavement which can be dislodged as vehicles pass over them. The remaining hole after the pavement chunk is dislodged is called a pothole. It can be Repair by excavating and rebuilding. Area repairs or reconstruction may be required for extensive potholes.

ii) **Patches:** An area of pavement that has been replaced with new materials to repair the existing pavement. Patch is considered a defect no matter how well they perform because it never completely meshes with the existing pavement nor is it structurally bound to it. The causes include the previous localized pavement deterioration that has been removed and patched, and also the utility cuts along the pavement. Patches are themselves a repair action, but the only way they can be removed from the pavement surface is by either a structural or non-structural overlay**.**

2.2.3.1.4 Surface defect

Surface defects are related to problems in the surface layer. The most common types of surface distress are:

i) **Raveling**: Raveling is the loss of material from the pavement surface as a result of insufficient adhesion between the asphalt, cement and the aggregate. Raveling typically tends to occur on an older pavement that have already oxidized. Raveling can be accelerated by traffic and other environmental conditions. A raveled pavement can be repaired with wearing course or an overlay.

ii) **Bleeding**: Bleeding occurs when the bituminous mix contains too much asphalt cement relative to the aggregates. In this case, the asphalt cement tends to bleed through the surface, hence, reducing the skid resistance of a pavement thereby making the pavement very slippery when wet, creating hazard to the road users. This problem is generally caused by the presence of excessive binder content in the mix and also using the binder with too low viscosity (too flow able) or an improperly applied seal coat. Bleeding occurs more often in hot weather when the bituminous binder is less viscous (more flow able) and the traffic forces the asphalt to the surface. The repairs include either the application of chip seal using absorbent aggregates or to mill off the top the top layer of the asphalt and apply a new course of hot mix asphalt (HMA) that contains a lower asphalt cement content.

iii) **Polishing**: it is a failure mode of the pavement surface consisting of rough exposed aggregates which is caused by excess repeated traffic on managing pavement system. It can result in a dangerous low friction surface with a decreased skid-resistance. Repair the surface by applying a skid-resistant slurry seal or a non-structural overlay.

2.2.4 Pavement Evaluation

Asphalt pavements deteriorate due to a variety of load impacts and environmental effects. Generally the most significant impacts are caused by repetitive heavy truck loads and water infiltration of pavement sections. The combined effect of these factors results in a deterioration curve that accelerates over time without the introduction of maintenance treatments to reverse or retard the decline.

The purpose of pavement evaluation is primarily to determine why the present pavement prevails so that the appropriate rehabilitation measures can be identified. Pavement evaluation involves detailing appropriate methods for pavement investigations, relating the symptoms of distress to their cusses and design using appropriate design method (AACRA, 2004)

According to (M.E.Zumrawi 2015) Reliable and cost-effective rehabilitation project require the collection and detailed analysis of data from the existing pavement. Such data are often categorized as follows;

- Traffic lane pavement condition (e.g. distress, smoothness, surface friction, and deflections.)

- Shoulder pavement condition
- Past maintenance activities
- Geometric design features
- Layer material and subgrade soil properties.
- Traffic volume and loading

There are different methods of determining pavement condition these are:

i) **Visual surveys:** visual surveys range from casual windshield survey conducted from a moving vehicle to the more detailed survey that involves a trained engineer and technicians walking the entire length of the project (selected sample areas) and measuring and mapping out all distress identified on the pavement surface, shoulders, and drainage system .recently automated visual survey techniques have become more common and are being adopted for distress surveys and pavement condition evaluation. Several methods are available to measure and quantify

In most cases, the raw data collected during the survey needs to be transformed for use in pavement evaluation and analysis.

ii) **Nondestructive testing data:** Nondestructive testing (NDT) is a term used to describe the examination of pavement structure and material properties trough means that do not induce damage or property changes to the structure. NDT ranges from simple techniques such as using GPR to determine in-situ layer thickness and condition, profile testing to determine pavement surface smoothness, friction testing to determine pavement surface –vehicle tire skid resistance, trough well-established method of deflection testing. Using A falling weight deflectometer (FWD).

Trough the most widely used forms of NDT are deflection, profile and friction testing, other forms of NDT (such as GPR) are becoming state-of-the art technologies. NDT typically has the following advantages:

- Reduce the occurrence of accidents due to lane closures
- Reduce cost
- Improve testing reliability
- Provides vital information for selecting between rehabilitation options.

- Provides data for rehabilitation (overlay)design

A key disadvantage to some NDT, such as deflection testing is lane closure.

iii) **Destructive Testing**: destructive tests require the physical removal of damage of pavement layer materials to obtain a sample (either disturbed or undisturbed) for laboratory characterization or to conduct an in-situ dynamic cone penetration (DCP) test. Destructive testing ranges from simple tests such as coring (and to determining the pavement layer thickness by measuring core lengths) to performing dynamic modulus testing on retrieved AC cores or determining the elastic modulus and strength of PCC cores. Other form of destructive testing that are less common are:

- Trenching of hot mix AC pavements to determine material condition and permanent deformations.
- Lifting of slabs of jointed concrete pavements (JCP) to determine subsurface material conditions.

Trenching consists of cutting a full depth, 4-6 in-wide strip of pavement. Full width of a traffic lane, and removing it to observe the condition of the different pavement layers over time. If rutting is present, it allows the engineer to determine where the rutting is located and the cause of rutting (consolidation or plastic flow). Trenching also allows the engineer to determine if and where stripping –susceptible asphalt layers lie in the pavement section. Destructive tests such as trenching is generally help to improve evaluation of the cause of surface distress.

2.3 Over view of road maintenance

According to the (Stankevich 2005), the main objective of road maintenance is to preserve the asset not upgrade it, unlike the major road works maintenance that needs to be done regularly. Unfortunately, maintenance is often neglected or improperly performed resulting in rapid deterioration of the road and eventual failure from both climatic and vehicle use impacts. It is accepted that the life of a road shortens due to factors with which maintenance activities cannot deal. Otherwise, maintenance intended to begin on the first day after the road improvement work is completed. Maintenance is done to ensure that the road that has been constructed, or improved is to the extent possible kept in its original condition. All roads require maintenance as they are subjected to traffic and forces of weather, even with the highest possible quality of construction.

Maintenance is essential to get optimum service from the road structure during the design life of the road (managing rural roads in India 2012).

If not maintained on time, roads rapidly become impassable to motorized traffic until a point when they are no longer trafficable. The pace of deterioration largely depends on initial construction, pavement and surface material, drainage measures, level of traffic and weather condition.

Road maintenance has a verity of definitions, some of them are:

- The Indian Road Congress (2010) defines road maintenance as "routine work performed to upkeep pavement, shoulders and other facilities provided for road users, as nearly as possible in their constructed conditions, under normal conditions of traffic and forces of nature". Maintenance is essential to get optimum service from pavement structure during the life period".

- According to ASCE (1971), road maintenance is defined under two sub divisions: physical maintenance and traffic services. Physical maintenance is the preservation and upkeep of a highway, including all of its elements, in as nearly as practicable to its original constructed condition or its subsequently improved condition." Traffic services are defined as "the operation of a highway facility and services incidental thereto, to provide safe, convenient, and economical highway transportation."

- AASHTO (1976), defined highway maintenance as a program to preserve, repair and restore a system of highways with its elements to its designed or accepted configuration. System elements include travel way surfaces, shoulders, roadsides, drainage facilities, signs, markings, lightening, fixture etc.

- World Road Association (1994), defined road maintenance as "activities to keep pavement, shoulders, slopes, drainage facilities and all other structures and property within the road margins as near as possible to their as-constructed or renewed condition" It includes minor repairs and improvements to eliminate the cause of

defects and to avoid excessive repetition of maintenance efforts. Maintenance does not include rehabilitation, building shoulders, or widening roads

In view of the foregoing, it is impossible to build and use a road that requires no maintenance. Probably the most valuable tool for any maintenance program is the knowledge and experience gained by individuals performing the maintenance. Every effort should be made to retain competent, knowledgeable, and experienced individuals in these positions, not only from the standpoint of instituting and executing a good maintenance program, but for future road planning needs as well.

2.4 Importance of road maintenance

Road network facilitate transport service and reduce costs of travel and trade; individual roads enhance accessibility to markets and service in most countries including Ethiopia, Roads are the major transport mode for both freight and passenger. According to the Asian Development Bank (ADB), 2013), Road networks have expanded in the Asia pacific region, and the freight and passenger transport will continue to grow along with motorization. Road improvements bring immediate and sometimes dramatic benefits to road users through improved access to hospitals, schools, and markets; improved comfort, speed, and safety; and lower vehicle operating costs. For these benefits to be sustained, road improvements must be followed by a well-planned program of maintenance. Without regular maintenance, roads can rapidly fall into disrepair, preventing realization of the longer term impacts of road improvements on development, such as increased agricultural production and growth in school enrollment.

Maintenance insures that the road remains serviceable throughout the design life. Maintenance is important because it:

- Reduces the rate of deterioration, thereby safeguarding previous investments in construction and rehabilitation:
- Lowers the cost of operating vehicles on the road by providing a smooth running surface:
- Improve safety of road users :and

- Improves the reliability of the road allowing it to remain open for traffic on a continuous basis and thus contributes to more reliable transport services and sustain social and economic benefits of improved road access.

Robinson (1998), in their book, "Road Maintenance Management Concepts and Systems" „stated the importance of maintenance as the following;

i) Reducing Deterioration: Eventually, the end of pavement design life will be reached and there is a need for pavement reconstruction or upgrading. These are normally relatively expensive and should be postponed for as long as possible carrying out effective and timely maintenance.

ii) Lowering Vehicle Operating Costs: (Robinison 1998), explained that the relative proportions of road administration costs and vehicle operating costs in the total life time transport cost with road vary depending on the traffic level. The relative proportion of vehicle operating cost rises from about 40 percent at 50 vehicles per day to over 90 percent at 6,000 vehicles/day. For a good condition road having a traffic level of about 1,000 vehicles/day requires 2% of discounted cost to be spent on maintenance. However, if maintenance funds are reduced, the pavement will start to crack and potholes will gradually appear and with these levels of deterioration, vehicle-operating costs are likely increase by about 15 percent. If there is complete neglect of maintenance, a paved road will eventually start to disintegrate and annual vehicle operating cost will increase by about 50 percent.

iii) Keeping the Road Open: (Robinison 1998), explained the third reason for carrying out maintenance as to keeping the road open continuously, since their closure for whatever reason causes potentially serious social and economic consequences.

iv) Safety: Accidents have proved to be an inevitable result of road transport and deaths and injuries are very tangible impacts of the roads on the community. Road maintenance works can often provide an opportunity for improvement of road safety by contributing engineering factors in the areas of pavement and foot way surfaces, carriageway markings and signs, streetlights and road furniture

(Mohamed 2010), in his thesis work, revealed the importance of road maintenance into three different aspects and. These are:

i) Time: Compared to time required for reparation and renovation on a structure, maintenance consumes less time, but can produce better quality results. Besides, work qualities for maintenance are also relatively lesser compare to reparation and renovation.

ii) Cost: definitely, the costs required by maintenance are lesser than the costs required to repair or to rebuild a structure. Furthermore, a specific structure can still be running under maintenance; hence, saving costs from the economic perspective. For example, closing a runway is a must for resurfacing, will lower the benefit that can be generated during that period

iii) Structure value and performance: Structure will have high value and good performance during its service life if maintenance works are done according to schedule and plan. Without proper maintenance, a structure will not be able to provide services at its maximum Performance all the time.

Carrying out timely maintenance on a road in a good condition will extend the life of pavement, as shown in the figure below. On the other hand, delays in executing maintenance generally leads to increased severity of deficiencies (i .e .poor or very poor condition) and can eventually leads to a need for complete pavement rehabilitation or reconstruction in later years. This can increase the life cycle cost associated with a particular pavement section. (Chairul 1991).

Besides the timing of maintenance execution, (Chairul 1991) stated that the strategy used to correct a deficiency can also have a significant effect on the performance of a pavement. The choice of strategy is also an important parameter in determining the long-term performance of a pavement.

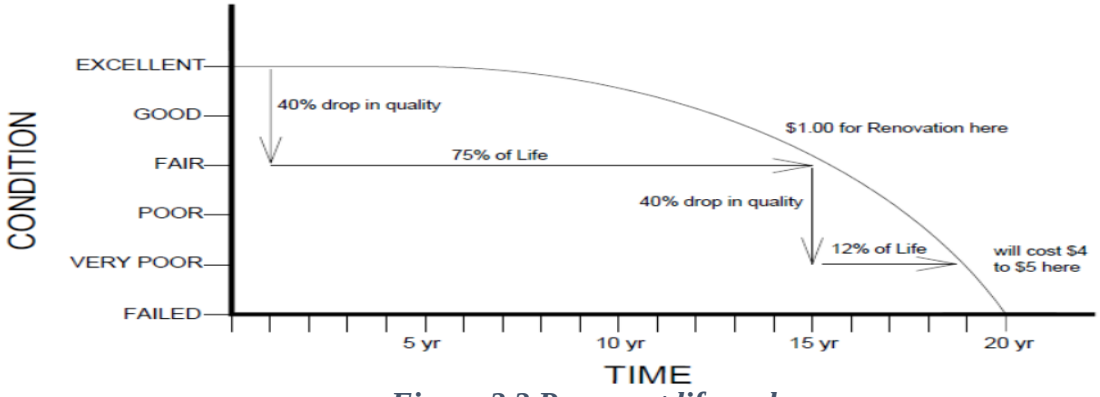


Figure 2.3 Pavement life cycle

Source :(Chairul 1991)

There is a problem, however, which is common throughout the world, the neglect of maintaining our roads. Building new roads cost money, but without maintaining the roads properly, they deteriorate very quickly. If nothing is done, roads with a design life of decades can need replacing or major repair work after just a few years. Some examples from different countries (Levik 2014) .Some examples from different countries of the direct cost of neglecting maintenance are:

- In Oslo, Norway, a bridge deck did not have adequate waterproof membrane. It could have been done as a simple job for a cost of approximately USD 0.6 million. The job was not given preference to and was therefore not done. The result was that the whole bridge after some years had to be torn down and replaced by a new bridge. The total cost for the new bridge was USD 15 million. In addition came the cost for the users, because they had to travel on lengthy detours for a long period of time.
- In Kenya, years of inadequate maintenance left the main Nairobi – Mombasa road highly vulnerable. In 1997 heavy rain damaged two bridges and several sections of the road. The result was that the users experienced months of national disruptions as long stretches of the road became unusable in the rains and very difficult in dry weather.
- In Tanzania, failure to improve a simple stream crossing caused damage to 3 kilometers of road – and led to lengthy delays. The result was a bill five times higher than would have been needed to make the original repair per Kilometer. If the maintenance is neglected, it will cost five or six times as much to restore the road. Economically, it is an indefensible waste. If money is short, and it usually is, there is only one rational course of action. Maintain existing roads before funding new ones and make sure it is done today, and every day. Tomorrow, it will be much more expensive (Levik 2014).

2.5 Road maintenance activities

According to (Stankevich 2005), for management and operational convenience, road maintenance is categorized as routine, periodic and urgent

i) **Routine maintenance**: Routine maintenance are activities which comprises small-scale works conducted regularly, aims "to ensure the daily possibility and safety of existing roads in the short-run and to prevent premature deterioration of the roads". Frequency of activities varies but is generally once or more a week or month. Typical activities include: roadside verge clearing and grass cutting, cleaning of silted ditches and culverts, patching, and pothole repair. For gravel roads, it may include regrading every six months (Stankevich 2005).

Routine maintenance: remains as the key activity as it is the least costly activity, which provides the greatest benefits. Some of the most common types of routine works are road patching, sealing of surface cracks, edge repairs, treatment for rutting and pavement repairs, re-grading of road shoulder, grass cutting, maintenance of road furniture, maintenance of bridges and culverts, cleaning of drains, landscaping, and routine inspection.(Regassa 2015) .

ii) **Periodic maintenance**: Periodic maintenance, which covers activities on a section of road at regular and relatively long intervals, aims "to preserve the structural integrity of the road" (WB Maintenance website). These operations tend to be large scale, requiring specialized equipment and skilled personnel. They cost more than routine maintenance works and require specific identification and planning for implementation and often even design. Activities can be classified as preventive, resurfacing, overlay, and pavement reconstruction. Resealing and overlay works are generally undertaken in response to measured deterioration in road conditions. For a paved road repaving is needed about every eight years; for a gravel road re-graveling is needed about every three years.(Stankevich 2005) .

iii) **Urgent maintenance**: Urgent maintenance is undertaken for repairs that cannot be foreseen but require immediate attention, such as collapsed culverts or landslides that block a road. Maintenance does not include rehabilitation, building shoulders, or widening roads. If the sections to be rebuilt constitute more than 25 percent of the road's length, the work is rehabilitation, not maintenance. (World Bank).

From the report by OECD Scientific Expert Group (1995), a Road Maintenance Management System (RMMS) is a maintenance management process aimed at systematically and objectively determining pavement quality and programming maintenance actions in response

to observed conditions, budgetary constraints and economic optimization (reduction of user costs, optimizing agency maintenance cost).

Effective road management requires a continuous access to information about every aspect of road network and the activities undertaken to keep it in a good condition.

The RMMS is a tool which provides assistance to the maintenance engineer for maintenance programming, implementation and monitoring.

The major objectives of a Road Maintenance Management System are the following:

- Provide the economic and managerial framework for deciding the optimal level of maintenance funding and the optimum level of pavement condition nationwide in both the long-term and short-term perspectives;
- Provide sound methods for developing annual works programmers and determine resource requirements and budgets;
- Allocate funds in a rational and optimized manner to the various maintenance tasks and administrations, particularly under budgetary constraints;
- . Schedule and perform the work;
- Monitor the efficiency and effectiveness of the works carried out; and
- Evaluate the consequences of delaying or postponing maintenance on future.

.This is implemented through road maintenance management process which according to(Chebou 2011) comprises main factors such as: road inventory, road condition survey ,road prioritization, road maintenance plan, tender evaluation and contract agreement.

2.6 Assessment of road maintenance management system

2.6.1Chinese pavement management system (CPMS)

This was an adaptation of road maintenance management system (RMMS) customized for Jiang su province road network in China (Robinison 1998), composed of), composed of three parts , the pavement data base ,network level management system, and the project level management system . The pavement data system (PDS) constitutes the information center for CPMS and performs activities like: data retrieval, edit, calculation, tabulation, statistics and other data as required .The network level management system (NLS) was a macro decision making system based on

investment analysis, maintenance demand analysis and pavement condition analysis at network level .The project management system (PMS) is a decision making system for maintenance of one or several road sections. It is composed of five modules. Data required for PMLS data preparation comprise: .pavement deflection, roughness, distress, friction coefficient etc. The decision method was used both on technical and economic factors.

2.6.2 Computerized road maintenance management system (CMMS)

A computerized maintenance management system is another tool that is widely used for asset management. .There now exists a large selection of fully commercialized CMMS. many of these are rational data base application that have been developed to meet the data handling needs of road managers .CMMS domain at this time, is quite mature and so many stable comprehensive useful tools are existing . The CMMS's capability to store inventory data is formidable, however, their capability with respect to life- cycle economics, service life prediction and risk analysis is considerably less sophisticated.

2.6.3 Road maintenance management practice in other countries

2.6.3.1 GHANA

Roads in Ghana is managed by the Ministry of Roads and Highways (MRH) through three agencies namely; Ghana Highway Authority (GHA), Department of feeder of Federal Roads (DFR), and Department of Urban Roads (DUR). GHA is responsible for planning, development, maintenance and administration of trunk roads which has transformed road maintenance over the 10 Years from predominantly force account (in house) approach to at least 90% execution of works by contracting. Road Maintenance Project financed both by GHA and Gesellschaft für Technische Zusammenarbeit (GTZ) is currently developing a computerized Road Maintenance and Management System (RMS) which seeks to provide tools for effectively and efficiently managing road maintenance in Ghana. This system is expected to cover planning, budgeting and work execution components. Under planning and budgeting component, road inventory, road condition survey and data storage system will be covered; under work execution component, maintenance activities, performance standards and work supervision will be considered Using advanced maintenance management systems; like computerized road maintenance management system will increase the efficiency and performance by decreasing the time required for paper work and by facilitating quality of work (GHA, 2007).

2.6.3.2 TANZANIA

Road works in Tanzania are managed by Tanzania National Roads Agency (TANROADS) and financed under the Roads Fund's Board which was formed established in the year 2000. TANROADS in 2002 worked with Transport Research Laboratories (TRL) in the development of a road management system under the Department for International Development (DFID) funding. The developed computerized road maintenance system, Road Mentor 4 is used as a network information system that assembles, organizes and stores data about road network in the country. The system covers road inventory, paved roads roughness and unpaved roads condition survey .again this system will increase the efficiency and performance of the Tanzania maintenance management by decreasing the time required for paper work and by promoting quality of work (TANROADS, 2003).

There is a greater need for (AACRA) to transform from manual maintenance management to computerized maintenance management in view of standardizing and increasing quality of work.

It is evident that countries including Ethiopia's neighbors are now adopting efficient advanced and computerized methods in road maintenance management which are customized to their needs. It is important for Ethiopia, Specifically (AACRA) to develop and utilize an efficient computerized road maintenance management system customized to the Ethiopia needs like the new procurement procedures.

2.6.4 Review of road maintenance management process

2.6.4.1 Road inventory

The purpose of the inventory data is to establish what there is to be managed and where it is located; It is a set of information about the basic engineering characteristics of a road network .(TRL1995).

(Chebou 2011) (2010) in his thesis work showed that the road inventory defines the key features of each section of the road and indicates the level of traffic use. The content road inventory should be directly relevant to maintenance management system the following items are included in road inventory:

- Type of surface
- Cross-section width, carriage way and shoulder, and

- Traffic volume

As the inventory built up, the information of the following items can be added

- Structure like; pipe culvert, box culvert and bridges;
- Socio-economic features along the road; and
- Road furniture like road signs, roadmaking and guard nails.

Data on other factors influencing maintenance needs are important, such as rainfall and runoff, topography and soil conditions. These factors can influence the degree of priority given to various operations when the work program me is prepared. In addition, data about the distribution and engineering properties of soils will be useful in identifying possible sources of maintenance materials.

2.6.4.2 Road condition survey

The condition of a road needs to be measured or assessed with sufficient precision to enable the need for repair or replacement to be established within a framework of priorities.

It is necessary to know the condition of the road every year for doing proper maintenance works. Accordingly, road condition survey is done to find out the condition, and should be done every year at a particular time. It is necessary because:

- It is possible to find out the condition of the road by doing the survey ,whether the roads are good, fair poor or bad
- Effective road maintenance requires proper planning and budgeting .by knowing the exact condition of the road; this could easily be prepared and the government can provide and distribute money accordingly.
- Road condition survey report provides proper data and information for feasible time period for periodic maintenance, rehabilitation and re construction work.

In the developing countries, visual methods are mostly used to survey the conditions of unsurfaced roads. The road conditions are used as indicators of the extent of maintenance activities required and to prioritize inventions.

2.6.4.3 Road prioritization

A common feature is that any prioritization of maintenance projects is concerned only with the forth coming financial year and it is based on the budget allocation arising from the network view. Prioritization becomes an effective for supporting decision to be taken for effective tool as maintenance management strives to achieve maximum benefit.

Vanier (1999) presents six "what" of asset management in order of priority as follows:

- What do you own?
- What is its worth?
- What is its condition?
- What is the remaining service life?
- What is the maintenance required?

Criteria used in the selection of roads should be by-and–large dependent on readily available information like road condition, population etc, or data which can be collected without much difficulty. Each selection criterion should be given numerical value and weight for ease of comparing various evaluation parameters.

There are various approaches for prioritization of roads; for example (Reddy and Veeragaven, 2004) developed a methodology of priority index to different sections based on their overall distress index model and traffic adjustment factors. (Chairul 1991)Conducted a study on prioritization of maintenance of UN -paved roads in the north east region of Brazil based on architectural analytical hierarchy method.

2.6.4.4 Road maintenance plan

From the maintenance ranking and with availability of funds, roads are earmarked for maintenance. The maintenance engineer and his staff do inspections in the field to determine what needs to be done depending on the conditions of the roads and availability of funds. A list of maintenance activities and their locations are then identified with their estimated quantities measured and the estimated cost of execution was determined using market rates. This is done to avoid variations during the implementation of maintenance works (Robinison 1998).

2.6.4.5 Tender evaluation

Tender evaluations largely depend on the procurement regulations of a country or organization. These procedures have to be standard with clear criteria set to promote openness and reduce corruption. Where it is possible computerized systems can be used for evaluation of bids in order to avoid any possible manipulation. (Chebou 2011)**.**

2.6.4.6 Contract agreement

This involves contracts schedules and time progress, monitoring of physical work progress, measurement and payment of works and reporting on financial progress. Important contract schedules like dates of contracts award, commencement of work, start of defects periods and end of contracts need to be recorded. These schedules help a maintenance engineer to monitor the time progress of contracts. Reports on physical work progress are very important in managing contracts. This enables an engineer to know which contracts are lagging behind in terms of physical work so as to find reasons and possible measures for improvement. Financial progress is also an important aspect of contract management since it can be used by an engineer to monitor how finance is used in a contract. In order to manage a contract efficiently, a good management system has to be used (Chebou 2011).

Generally, the road maintenance management cycle shown in Figure below

Figure 2.4 Road Maintenance Management cycle

Source :(Chebou 2011).

2.7 Road maintenance management in Ethiopia

The concept of road maintenance management is not new in Ethiopia .ERA has been implementing pavement management system to effectively maintain and upgrade road assets. AACRA also had a SMEC road maintenance management system until 2010 as it fails.

2.7.1 over view of ERA Pavement management system

ERA pavement management system organized with different PMS user manuals. Among these user manuals, PMS user manual for PMS Operations is the leading one which includes all procedures in PMS. This PMS User Manual describes the operational actions necessary to maintain and support the data management of the Pavement Management System of ERA (pavement management system).the manual here below describes all supporting documents for ERA's PMS.

ERA PMS User Manual for dTIMS and HDM4 Operations; this manual describes the customized PMS systems of ERA in the dTIMS and HDM-4 software applications. It includes database operations in dTIMS and life cycle cost analyses in HDM-4.

ERA Manual for HAWKEYE Data PMS User Processing; this manual describes the processes to be followed after a road survey has been completed with the HawkEye equipment. The manual has details on how to process and export the profile and distress data, and how to further manipulate the surveyed into the correct format for importing into ERA's dTIMS database.

Official set of HDM-4 Manuals; this manual suite contains the following documentation on the HDM-4 series: Applications Guide, Software Users Guide, Assessing Ethiopian Roads Authority's (ERA)'s Pavement Management System (PMS) Analytical Framework and Model Descriptions, a Guide to Calibration and Adaptation, Modelling effects.

dTIMS V8 User Guide March 2011; This is the official User's Guide of the Dtims software application. It describes all aspects of the dTIMS software application that are necessary to maintain a road network database in dTIMS.

(Seid 2015) in his thesis work showed that ERA's pavement management system operation consists of:

i) **Data Collection Equipment**: Data collection for the PMS is done through the Hawkeye 2000 (on paved roads) and Hawkeye 1000 (on unpaved roads) systems. The Hawkeye 2000 system is installed in the Mercedes Benz Vito vehicle and provides data for paved roads such as roughness, rutting, cracking, raveling, potholes, structural failures and drainage facilities. The Hawkeye 1000 system is installed in the Nissan Patrol station wagon vehicle and provides data for unpaved such as roughness, wearing course quality, wearing course quantity, and drainage condition. Once all data has been processed in the Hawkeye Toolkit software, and validated, merged / combined in the special pre-processing software application, they are imported to the dTIMS database. A special conversion application is then executed to convert the data to HDM-4 input file requirements. Life cycle strategic and program analysis then follow in HDM-4 for decision support to ERA Management on maintenance strategies and long-term program Apart from the above equipment ERA also operates a Falling Weight Deflecto-meter (FWD), trailer mounted and towed by another Nissan patrol station wagon vehicle. The FWD provides structural strength information about road pavements. The structural strength information is captured in HDM-4 to represent the current strength of the pavements.

ii) **Day to day operations**: The maintenance of any PMS is an on-going continuous task.it includes activities like processing survey data and importing data to era dTIMS and updating it continuously.

iii) **The start of a new survey cycle:** At the start of each survey cycle, ERA's road network to be surveyed should be identified in a list of paved and unpaved roads. The list of roads can then be distributed to the surveyors and PMS personnel involved with the monitoring of the annual surveys.

iv) **Traffic data in the "Traffic" perspective in dTIMS:** Traffic data is an important component into the strategic analysis of ERA's road network in the HDM-4 software. It influences road user costs in an economic analysis, it influences the rate of deterioration on roads and it plays an important role in the strategic planning of road works under constrained budget scenarios.

v) **Falling Weight Deflection (FWD) data:** Deflection data collected from the FWD equipment should be stored in the "FWD" perspective of ERA's dTIMS database. The FWD data collected for any portion of the road network should be imported into ERA's dTIMS database and will then automatically be included in the HDM-4 analysis.

vi) **Details on the condition index:** The Condition Index (CI) describing the overall condition of road. The processed profile and distress data is used to calculate a single Condition Index (CI) describing the overall condition of a road segment, for a specific year. This CI, calculated for each surveyed road segment, is a percentage index ranging between 0 and 100; 0 representing a road segment in very poor condition and 100 representing a road segment in very good condition. An average network CI is calculated representing the average condition of the unpaved road network for a specific year. This average network CI is weighted by Length. The CI can be grouped into five condition categories that are used to categories the condition of the paved or unpaved road network into very good, good, fair, poor and very poor categories. The categories adopted are:

- Very good=86%to 100%
- Good = 71%to 85%
- Fair =51%to 70%
- Poor =36%to50%

- Very poor=0%to35%

(Seid 2015) (2016) in his thesis work revealed the problems occur the process of pavement management system of ERA are:

- Shortage of trained staffs (i.e. only one staff trained on PMS)
- No sufficient for the staff
- Data of road: the data was not too accurate and also the problems to keep the data in systematic manner.
- Do not fully implement the standard manual in PMS in this regard ,since the revised PMS launch in 2011, ER has been conducted only level 1 calibration of HDM-4 ,level 2 and 3 are not yet conducted.
- Breaking down of data collector equipment's and delay of its maintenance
- Lack of awareness of data collector personal
- Lack of timely model calibration and validation
- No timely perform PMS
- For already surveyed 6000 Km major roads HDM-4 was not analyzed

Hawkeye 2000 Series

- One of the laser sensors were damages on a survey
- Error was encountered and the whole system froze.
- Upon launching all necessary modules, the status of the profiler stays on "not connected.

Hawkeye 1000 Series

- Currently operating for roughness measurement of asphalt roads. (Having difficulty with gravel roads but it is designed for unpaved road.)
- Stops operation after 2-10 km
- There is some problem with the DMI (disconnected from the wheel).
- Hydraulic system failure of FWD

The above mentioned problems affect the implementation level of ERA pavement management system. Hence, problems needs to be identified in order to improve the current pavement management system.

2.7.2 Road maintenance management system in Addis Ababa City Road Authority (AACRA)

2.7.2.1 Overview of Addis Ababa City Road Authority

"Addis Ababa, the capital city of Federal Democratic of Ethiopia, is located at the center of the country .The city was founded by Emperor Minellik II and Empress Taitu in 1987.Minellik II constructed the first ever two roads in the city as well as in the country that stretch from Addis Ababa to Addis Alem and from his place to British embassy in 1902.

The country's modern road construction is highly interlinked with Emperor Haile Sellase's ruling period. During the regime of Haile Sellase I a number of contractors were organized to carry out road construction.

When it was decided for Addis Ababa to have a mayor and a council in 1942, the city roads construction and maintenance was organized under the municipality. To fulfill the road construction activities together with building works the "Road and Building Works" department was established. This department stayed till the replacement of the Haile Sellase regime by the Derge regime performing its duties. But no fundamental organizational change of the department was observed in the Derge regime.

In 1993 the EPRDF has established regional governments and gave them power to administer their regions with autonomy. During this time Addis Ababa Was also established as one of the regions. The Addis Ababa Administration during this period established the "bureau of works and urban development" and the bureau organized a department under it to carry out the road construction and. maintenance works. The newly established road department constructed and maintained the city roads till the establishment of the Addis Ababa city Road Authority in March 15, 1998 by regulation No. 7/1998 to be administrated by board of directors to construct maintain and administer the road work in Addis Ababa by the city Administration.

Addis Ababa lies at altitude of 7,546 feet(2,300 meters) and is a grassland biome ,located at coordinates : 9°1´44´´N, 38°44´24´´E 9.03°N ,38.74° E9.03;38.74.the lowest point, around Bole International Airport, at 2,326 meters (7,631ft) above sea level in southern periphery, the city rises to over 3,000 meters (9,800 ft) in the Entoto mountains to the north.

According to the 2007 national census, the population of Ethiopia has reached73, 909,355 of which urban population was 11,956,170 accounting for 16.1% of the total population. Having a

growth rate of 2.1%, the population of Addis Ababa was 2,738,248 which accounted for 32.27% of the total urban population of the country (Central Statistics Agency, 2010). The expansion of the city, increasing population size coupled with the economic growth has required respective transport service supply for the increasing mobility needs of the People.

According to (Alebachew 2005), the road construction and maintenance works in Addis Ababa until1996 were not organized with proper human power, equipment and material resources. Such inadequate resources coupled with organizational shortcomings within the municipality such as lack of formal policy and standards for road Construction and maintenance has resulted in substandard maintenance services which directly or indirectly affect the pavement performance as follows.

- Materials and construction quality control & tests were not performed at all. As a result, it was not uncommon to encounter pavement failures distresses within short time after the new roads are opened to traffic.
- Different administrative bodies of the city government such as Higher, Woreda, Kebele and other agencies constructed most of the Road network without following the master plan and appropriate standards.
- Lack of integrated infrastructure development is the other problem affecting the road network. There is no proper coordination with local Agencies, which carry out utility constructions such as water works, telephone lines, power lines, sewer lines and etc. Due to this, there is repetitive destruction of the existing road pavement and drainage structures, which consequently cause bumps, sags, patch deterioration another damages on the asphalt due to water infiltrating in to the cracks.

In addition to the above shortcomings related with the network, the road construction and maintenance has the following problems:

- No proper pavement evaluation,
- No proper quality control during construction and maintenance
- No coordination between different bodies involved in the road construction and maintenance.
- Do not comply with the city master plan, appropriate design standards and construction practice,

The above construction and maintenance problems are aggravating deterioration of roads and consequently repeated maintenance and repair is being made.

AACRA constructed 2,510 Km of asphalt road until 2013/14 fiscal year, more than double the network coverage of the city 13 years ago. Before the establishment of AACRA in 1998, the city roads were constructed and maintained by the road construction department under Addis Ababa city administration. The total length of asphalt roads constructed in the city until the establishment of the authority was 970 Km. the total length of the city including gravel and coble stone roads reached 4,614 Km as of June 2015.

According to AACRA magazine 2014): arterial, sub arterial, collector, local, coble stone and gravel roads in Km are given table below:

Table 2 1AACRA road network coverage

Types of road	Road length in Km
Arterial	1,130
Sub arterial	425
Collector	342
Local	267
Coble stone	1,330
Gravel stone	1,176

Source: AACRA magazine 2014 edition

2.7.2.2 Road Maintenance Management System in AACRA

Road maintenance management system is not a new concept for AACRA.in 2004 AACRA attempted to introduce a Snowy Mountain Engineering Corporation (SMEC) RMMS based on HDM-4, but this attempt was failed due to:

- Considerable number data was required
- No trained staff in AACRA(resign, turnover)
- System cannot be customized.

Since 2010, after SMEC was failed road maintenance management system of AACRA has become very poor and prone to many problems .in order to improve these poor road maintenance management system collaboration agreement was signed between AACRA and JICA in July 2015 for development of road maintenance capacity of Addis Ababa. The purpose of the project is to enhance the management capacity of AACRA for road maintenance

The expected output of the project are:

Development of road data base: it involves setup target road (start point and end point) ,formulate inventory and condition survey information ,preparation of survey schedule and staff assignment.

Establishment of road maintenance management system: procedures in RMMS are given in figure below

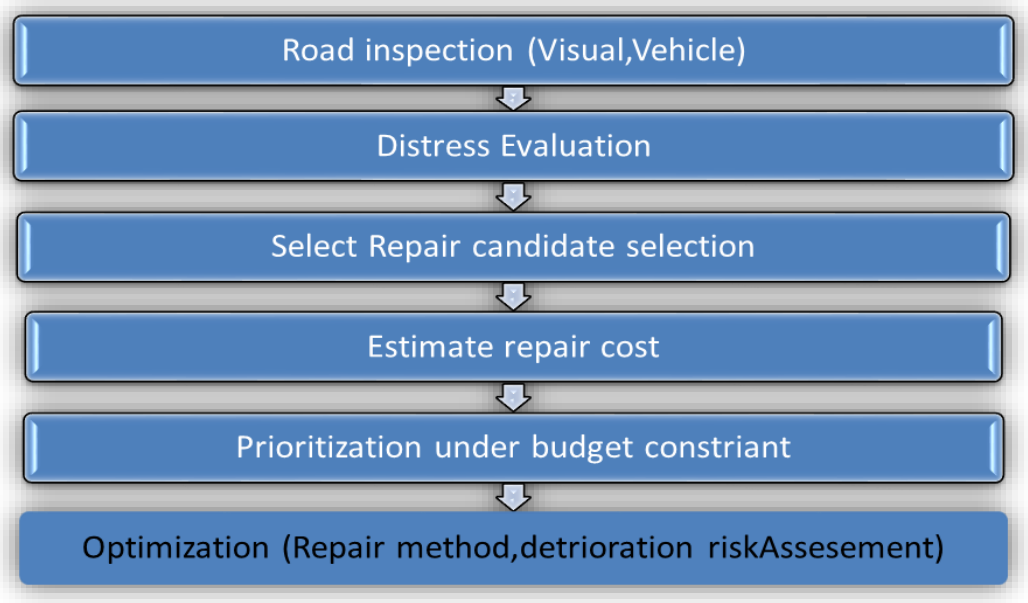


Figure 2.5 procedures in RMMS

Source: AACRA Seminar Report

Technology transfer: it involves using instruments for structure test for destructive and nondestructive test: for destructive, portable failing weigh deflectometer (FWD), and dynamic cone penetration (DCP), while for destructive test: falling weight defelectometer and Benkelman beam.

Capacity improvement of AACRA"s staff: continuous trainings through workshops, on the job trainings (OJT), kaizen in office and overseas

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The aim of the research is to develop a computerized road maintenance management system of the Addis Ababa City Road Authority (AACRA) in respect of work standardization, increasing efficiency and enhancing productivity. The weaknesses of the current road maintenance management system in AACRA were identified through acquisition and analysis of primary and secondary data. The primary data were gathered through questionnaire, interviews and condition survey while secondary data were collected from reports, documents, and literatures. Subsequently, the collected data were analyzed and descriptive statistics would be generated, including average index. As a solution Computerized Road Maintenance Management system were developed based on findings**.**

3.2 The study area

The location of the road network considered in this research was Addis Ababa, the capital city of Ethiopia. Addis Ababa, is currently rapidly growing in to a metropolitan city with extensive developments in respect of Infrastructure, Tourism, Education, passenger, and fright movements, rapid population growth, spatial expansion. However, negative impacts are produced as well as such as; traffic congestion, road accidents, vehicle emissions and noise etc.

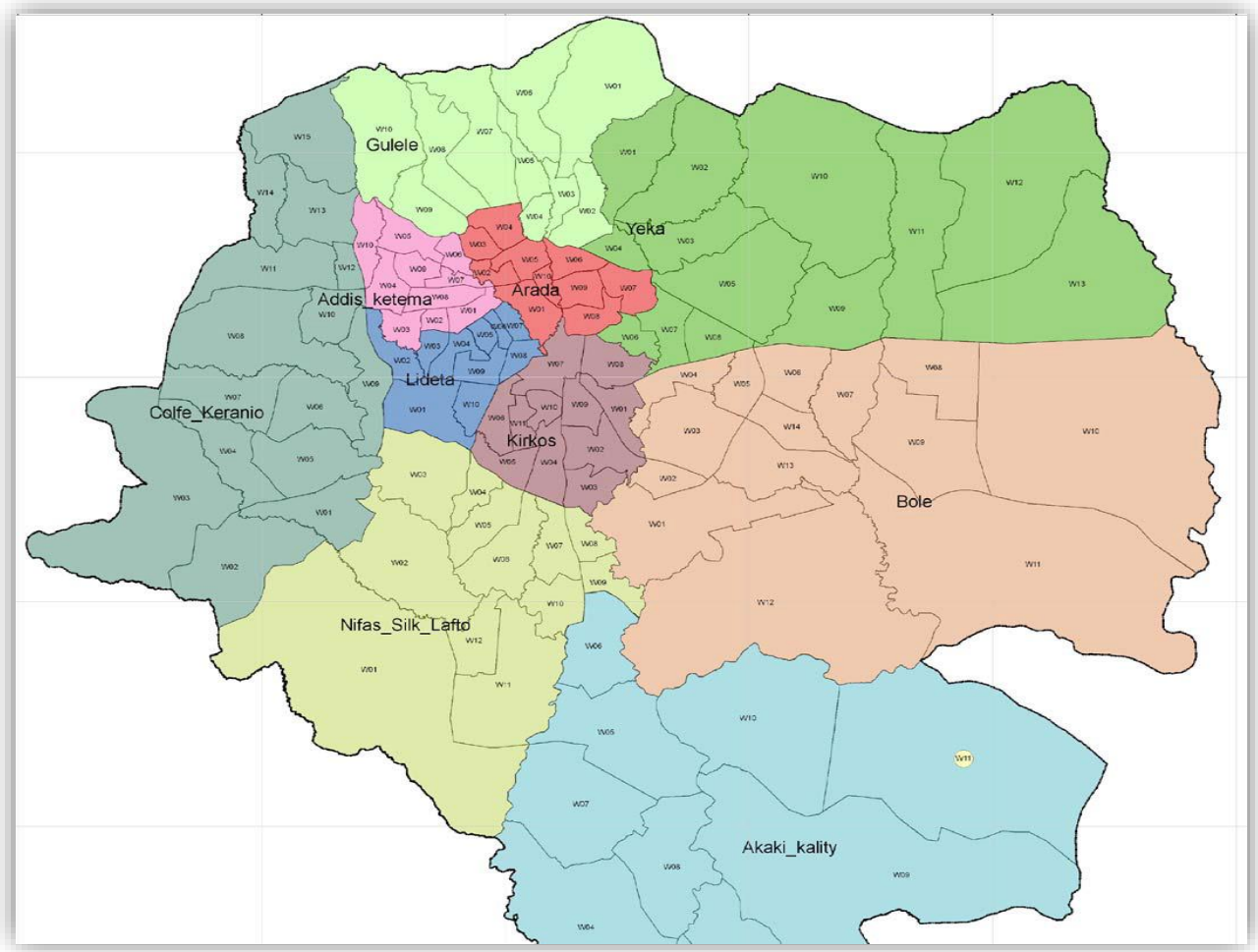


Figure 3 1ayout of Addis Ababa City Administration

Source: City development plan (2001)

3.3 population and sampling technique

The target of the study is made all staff members of AACRA; mainly, road assets management and maintenance engineers involved in ORF; experienced engineers workings at different consulting office with capacities of supervision maintenance activities. The size of sample was based on consideration that; all the selected members fully understand the processes involved in the execution of maintenance projects: the distribution of the samples are given in Table 3.1 below.

Table 3.1 Sample distribution

Organization	Frequency
AACRA	15
ORF	5
Consultants	50
Total	70

3.4 Data collection

3.4.1 General

Normally, there are two ways of data gatherings: secondary data collection from published and unpublished documents and primary data collection through interview, distribution of questionnaire and site visit (Visual inspection).

3.4.2 Secondary data collection

Desk study was used as one of the instrument of data collection to assess and obtain reasonably complete information and knowledge at the road maintenance management systems and practices from relevant studies, journals reports, books and documents.

3.4.3 Primary data collection

3.4.3.1 Interviews

Interview involved face to face communication between the interviewer and the interviewee .the purpose of the interview was to assess the current practices and perceptions and to obtain the

required data regarding road maintenance and management. As a whole, interview consists of three questions:

- Question No.1: focused on the current road maintenance management system (RMMS) in the Addis Ababa City Roads Authority (AACRA).Mainly, the questions were like: "what types of road maintenance management system do you use in your office?", Do you think the current road maintenance management system in AACRA is satisfactory?" and" " if not "What are the weaknesses .
- Question No.2: focused on how to improve the current road maintenance management practices in AACRA with questions like: "Do you think providing enough funding will improve the current RMMS weaknesses?" and "Are there actions taken to improve the RMMS and what are they?"
- Question No.3 focused on questions like "Do you think Computerized Road Maintenance Management System (CRMMS) will be a solution to improve the current weaknesses?" Overall, the questions were intended to achieve the objectives of the research.

3.4.3.1 Questionnaires

Questionnaires were developed and distributed to concerned persons to obtain the required information .In this study, a questionnaires was sent to AACRA to obtain data on current practices of road maintenance management system. The questions in the questionnaire were focused on road maintenance management processes namely: road inventory, road condition survey, road prioritization, and road maintenance plan and contract agreement. The questionnaire has three main parts as follows:

- PART I focused on respondent's characteristics :(" sex, age , level of education and work experience ")
- PART II focused on current road maintenance practices in AACRA, It mainly consists of road inventory and road condition survey with questions like "How often do you carry out road inventory and condition surveys?"; "What methods do you use for road inventory and condition survey?"; "What difficulties do you face during road inventory and condition surveys?", Regarding road maintenance prioritization, road maintenance plan and contract agreement the questions were like: "Is there any particular prioritization criteria in your organization?"; "What particular maintenance prioritization criteria do you use in your

office?"; "How frequently are technical, socio-economic and government factors considered during maintenance prioritization ?"; "Do you prepare annual maintenance plans?"; etc..; and

- PART III focused on challenges faced during maintenance management implementation practices and approaches to improve the current road maintenance management system and the questions were like: "How effective is the road maintenance management system used in your office?"; " What are the most important factors affecting road maintenance practices in your office?"; " What are the challenges faced during implementation of road maintenance management practices?"; "What should be done to improve the road maintenance management system?"; etc. .Detail research questionnaires and formats are included in the Appendix.

3.4.3.3 Site visit

Site visit was used to capture major structures found along a road like culverts, major socio-economic features and road signs along a road and Evaluate whether maintenance activities are performed according to the road condition survey findings and quality standards.

3.5 Data Analysis

The method used to analyze the data acquired through "interviews and questionnaires" was through calculations of descriptive statistics. The calculation were done using the MS- Excel software. This method of analysis helps to quantitatively examine the response. All the collected data were organized, analyzed and the generated result were summarized in order to reach at meaningful conclusion. As mentioned above, the MS-excel was used for primary data analysis and organization and the results were presented in tabular formats. Secondary data were used as a supplementary source of information. The generated results are described below.

3.5.1 Average index

As stated by Majid and McCaffer (1997) in their research works, the average-index is calculated using the following formula:

$$AI = \frac{\sum \alpha i Xi}{\sum xi}$$

Where,

AI: average index

ai:= constant that represent the weight of I;

Xi: variable that represents the respondent frequency for

i:=1,2,3,4

To determine the satisfaction level on maintenance management system, the average index method with five different scales were used and the scales are shown below:

1 = extremely effective 3.5<AI<4.0

2 = Very effective 2.5<AI<3.50

3 = moderately effective 1.5<AI<2.50

4 = Ineffective 0.5<AI<1.50

5 = extremely ineffective 0.00<AI<0.50

The numbers assigned to the agreement or degree of influence (0, 1, 2, 3, and 4), do not indicate that the interval between scales are equal, nor do they indicate absolute quantities, they are merely numerical labels: Table 3.1 below presents the research occurrence scale.

Table 3.2 occurrence scale

Degree of occurrence	4	3	2	1	0
Scale	Extremely effective	Very effective	Moderately effective	Ineffective	Extremely ineffective

3.6 Method used in designing and developing the proposed computerized road maintenance management system (RMMS) for AACRA.

Based on understanding and the results of the current maintenance practice of Addis Ababa and from the analyzed data collected from the questionnaires, a road maintenance management model was developed with modules as shown in Figure below which form a complete road maintenance management cycle in case of Addis Ababa city.

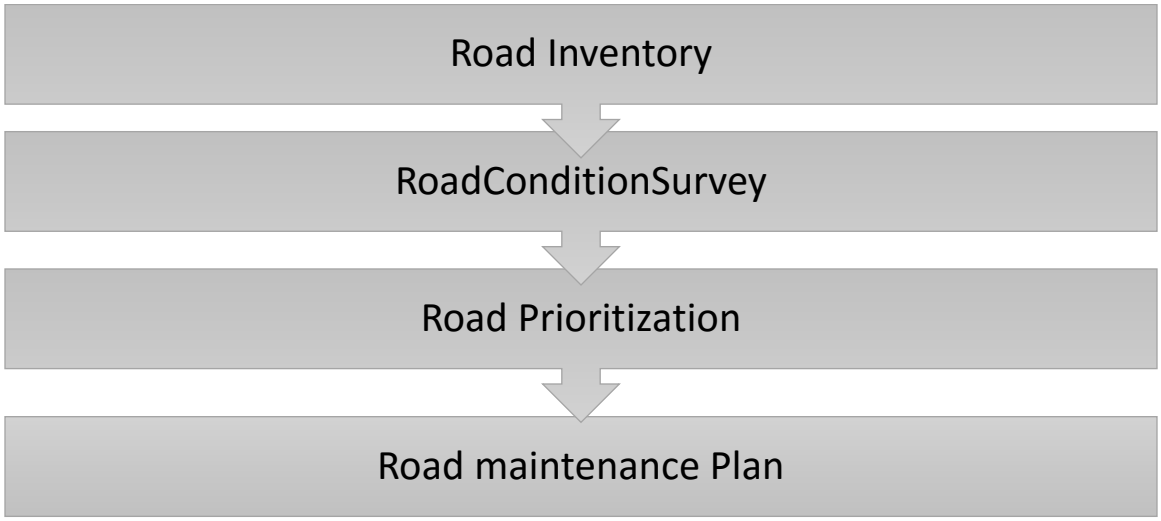


Figure 3.2 RMMS module design process flow chart diagram

After Road Maintenance Management modules were developed, Databases were then developed for each module using Microsoft Sequence Query Language 2014 (MS SQL 2014) server. This was chosen because:

- ✓ It has powerful data handling and processing capabilities making it an overall lead in developing an application that has high data requirements.
- ✓ It is easier and faster to build a database since it is readily structured.

The interface design was developed using Visual Studio 2013. This was chosen because;

- ✓ It is a visual-oriented language; it aids user training, learning and support hence raising user acceptability of the system.
- ✓ It is enhanced with graphical components thus enhancing the design of a user friendly interface.
- ✓ It has the facility to create highly complex yet easy to use interfaces.

CHAPTER FOUR

ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter deals with the analysis of information gathered through desk studies, interviews and questionnaires. The purpose of the analysis was to generate indicators regarding AACRA on the current road maintenance management system and problems of road maintenance management system and in the Authority. Interviews were conducted with key informants involved in road maintenance activities in AACRA in order to understand the prevailing road maintenance management system.

Questionnaires were distributed and responses are collected in respect of: the current road maintenance management practices and problems of current road maintenance management system.

The questionnaire had five sections : (i) respondents' characteristics; (ii) capturing data on road maintenance management processes: road inventory, road condition survey, road maintenance prioritization, road maintenance plan, tender evaluation and contract agreement, (iii) problems affecting road maintenance management; (iv) challenges encountered during road maintenance management: and (v) basic approaches to improve road maintenance management. Respondents of the questionnaires were engineers working in AACRA and in the Ethiopian Road Fund Office who were involved in road maintenance practices. From the responded questionnaires, relevant data were sorted out and analysis was done. MS Excel was used to generate descriptive statistics and average indexes and the results were presented in terms of frequencies and percentages.

4.2 Findings on Current Road Maintenance Management

The results from the questionnaire were analyzed in respect of frequencies and percentages.
These enable to have a deeper knowledge about the current maintenance management practices.

4.2.1 Road inventory and condition survey

All respondents confirmed that road inventory and condition survey were conducted annually. However; it was found that there is no defined schedule for conducting road inventory and condition surveys. Mostly, they are conducted when roads are in poor condition and cannot provide the required services and also when the pressure by the public gets stronger. Generally, the method

of carrying out the survey is traditional where, data are not structurally organized and stored in data base system.

Recently to improve the data collection system, AACRA have planned to use visual inspection support system consisting smart phone applications and GIS method, pavement condition survey and vehicle, instruments for road structure test both destructive and non-destructive.

The respondents indicated that AACRA use its own method for carrying out road inventory and condition survey. It was found that the road inventory and condition surveys were appropriately conducted using the Snowy Mountains Engineering Corporation (SMEC) system during 2004-2010. The SMEC road inventory format consists of important parameters like:

- Start chainage;
- Measured length;
- End chainage;
- Pavement surface type;
- Surface width;
- Carriage way;
- Road class; and
- No of lanes

Condition of the road were rated as Excellent, Very good, Good, Poor and Very poor. During 2010-2016, the road inventory and condition survey were not separately and appropriately conducted using the standard formats. To overcome this problem, AACRA in collaboration with the Japan International Cooperation Agency (JICA) prepared a standard format .the road inventory format consists of important parameters like:

- Status of the road –(existing /new);
- Road class;
- Direction of the road -(up/ down);
- Station ,segment and length;
- Strategic road;
- Road / street names;
- Start of the section;

- End of the section;
- Junction type;
- Pavement type; and
- Latest maintenance history

As stated above, the road condition was rated as: Very good, Good, Poor, Very poor. Data were gathered using this format and it was found satisfactory but needs some modification.

The major difficulties faced during carrying out road inventory and condition survey were inadequate funding, transportation and manpower. Road inventory and condition were conducted in traditional way so it takes more time and the majority of works were handled in hard copies and involves lots of paperwork. It is hoped that the recent changes in AACRA organizational structure will solve these problems: mainly transportation and manpower challenges. JICA had carried out road maintenance capacity development in AACRA. One of the expected output is database, it hoped that it will minimize paper work and saves time.

The results presented in the above show that the road inventory and condition surveys were not appropriately conducted, using standard and consistent formats and also don't cover full stretch condition survey, they undergo few kilometers per year. This results in unreliable data for maintenance planning and prioritization. Data on factors influencing maintenance needs such as rainfall and runoff, topography and soil conditions were not included in the AACRA'S inventory format. These factors can influence the degree of priority given to various operations when the work program is prepared. In addition, data about the distribution and engineering properties of soils will be useful in identifying possible sources of maintenance materials and they should be incorporated during road inventory. Since this data is required to ensure proper planning, monitoring, as well as to assist funding allocation and key policy developments, they have to be carried out using advanced data collection tools and standardized formats. Generally, no other evaluation mechanisms than visual inspection is used for structural, functional and safety evaluation which has significant role in justifying the causes of asphalt distress; so that to suggest the effective remedial action.

4.2.2 Road prioritization

All respondents showed that funds allocated for maintenance activities are not enough for carrying out maintenance activities. In order to effectively use the allocated maintenance budget, it is important to categorize the condition of the road which need maintenance in coming financial year. It needs careful maintenance prioritization criteria, so that the one technically and economically viable roads are considered for maintenance.

In AACRA, 71.42% of the respondent confirmed that they use their own criteria for prioritization of roads for maintenance purposes, while 28.56% indicated that they depend on the government's interest in addition to their own criteria.

AACRA gave special priority to roads identified by them as strategic roads; they were maintained year-to-year mainly due to government influence without considering technical and socio-economic factors for prioritization.

Table 4.1 below shows some examples of strategic roads identified by AACRA. It was found that there is no particular criteria followed by AACRA for prioritization of maintenance activities. The method used is subjective; roads were prioritized through discussion with the higher AACRA officials without following standards and criteria. With respect to the condition of the road and their experience on maintenance activities, engineers in AACRA use, 50% for technical factors, 30% for socio-economic factor and 20% for governments influence factors and are considered during maintenance fund allocation. It is known that the funds used to maintain roads are those collected from tax payers, then a more equal approach should be used in prioritizing roads for maintenance. Therefore, there is a need to develop a standard criteria for prioritization of roads for maintenance. It is recommended to prioritize roads by considering technical and socio-economic factors, in addition to stakeholders and governments influence. Table 4.2 about grading of prioritization factors

Table 4.1 strategic roads identified by AACRA

No	Road name	Start of the section	End of the section
1	Minelik II Street	Mesekel Square East	Economic Commission for Africa
2	Minelik II Street	Hilton Hotel	National Palace South
3	Niger Street	National Palace South	National Palace South-East
4	African Avenue /Bole Road	Olympia Square	Wollo Sefer Square
5	Ras Abebe Aregay	Mexico Square	ERA
6	Chad Street	Mexico Square	St Lideta Medical Collage
7	Jemo Keniyata Street Avenue	Meskel Square	Meskel Square West

Table 4.2 Grading of Prioritization factors

Decision making criteria	Average (%)
Technical factor	50
Socio-economic factor	30
Government influence	20
Total	100

4.2.3: Road Maintenance Activity plan

Road maintenance plan shows when the actual specific maintenance activity at specific place is implemented. It was planned by planning officers based on condition survey and prioritization data. Table 4.8 below shows the method used for preparation of annual maintenance plan; 93.3% of respondent confirmed that they use their own criteria for assessment of quantities to determine the volume of work and ORF criteria to estimate total cost of individual maintenance activity. But the method used for assessing quantities was not accurate; variation of quantities resulted during actual implementation maintenance activities. Unit price for specific individual work is already fixed by ORF and they use this unit price to calculate total cost of the given maintenance activity. The road maintenance plan comprises the following points:

- Road number;
- Width and length of the road;
- Start of the section;
- End of the section;
- Maintenance type;
- Maintenance cost (unit price and total cost);
- Maintenance sequence; and
- Maintenance time (1st quarter physical, 2nd quarter, 3rd quarter and 4th quarter fiscal year).

Table 4.3 Road maintenance plan preparation criteria

Decision making criteria	Frequency	(%)
AACRA own criteria	6	8.57
Both AACRA and ORF criteria	64	91.42
Total	70	100.00

4.2.4 Tender evaluation

Table 4.9 below shows the methods used by AACRA when tenders are evaluated. All respondents indicated that they use the criteria set by ORF to evaluate tender documents.

In AACRA road maintenance activities were conducted by their own force (force account method) and road maintenance activities are privatized to private contractor. So, there is no tender evaluation process between AACRA and the contractor.

ORF has been providing separate budget for supervision of maintenance program management to monitor and evaluate road maintenance activities to ensure quality of work.

AACRA use ORF evaluation criteria for evaluating tender documents to award supervision and consultancy work.

(i) Technical criteria: Technical criteria and maximum number of points are given in Table 4.10 below.

Table 4.4 Technical evaluation criteria

Criteria	Maximum point
Specific experience of bidder related to the assignment	10
Adequacy of the proposed work plan and methodology	25
Qualification and competence of the key personal for all assignment	53
Suitability of the transport knowledge program and proper service	10
Participation of nation (as reflected by nationals among key staff)	2
Total points	100

ii) Financial evaluation criteria: To determine financial scores for each proposal, the lowest priced proposal shall be given a financial score of 100, and other proposals shall be given a score proportionate to this, by application of the following formula:

Sf = 100 xFm/Fin

Where:

Sf: financial score of the proposal under consideration;

Fm: the price of the lowest financial proposal that passed the technical evaluation;

F: the price of the proposal under consideration.

A total score (S) will be determined for each proposal, by combining its technical (St) and financial (Sf) scores using the following formula and weightings:

S = (St x T %) + (Sf x P %)

The weights given to the scores of the Technical and Financial Proposals are:

T = [70 - 90]

P = [10 - 30]

Proposals will be ranked and the proposal achieving the highest total score will be recommended for contract award, subject to satisfactory negotiations.

According to the ORF Terms of Reference (TOR), it was found that the duration of the consultancy service was 12 months. Consultants were changed every year or within 2 years duration. This makes very difficult to build strong and consistent work plan.

4.2.5 Contract agreement

AACRA carries out maintenance activities on force account method by using their own resources. But, consultants hired by AACRA on behalf of ORF, every year. According to the TOR prepared by ORF, the consultants will have the following responsibilities (ORF TOR, 2015):

- To supervise the road maintenance program with particular emphasis on scheduling of activities, checking and verifying accurate measurement of work done, certifying payment, and quality control, social and environmental issues as per agreed specification;
- To identify and report problems that hinder the smooth and efficient delivery of the road maintenance programs in Addis Ababa;
- To monitor and evaluate the progress of the road maintenance program against agreed targets;
- To review unit prices for road maintenance activities of the respective Road Authorities in order to effect payment based on agreed unit price.
- To ensure material quality, workmanship, proper payment certification and technical reports.
- To check that the maintenance measure for the existing road has been carried out in sufficient details to restore pavement widths and conditions;
- To check that the maintenance measure provided in the contract with regard to major and minor structures and road side drainages for adequacy of flow and problems of erosion and siltation is sufficient.
- To perform all required design changes /modification/ amendments, additional design necessary or advisable as an outcome of the above services to suit field conditions during

maintenance. The outcome should be prepared as maintenance measures review report and submitted to the client with recommendation.

- The finding during the study showed that, the consultant is currently approving payments only as its main activity. Quality checking, taken measurements and other activates set on TOR not carried out by the consultant and this is one main weakness of the contract administration at AACRA.

4.2.6 Summary of findings on current road maintenance practices in AACRA

The main findings on current road maintenance practices in AACRA are summarized as below:

- Road inventory and condition survey were conducted by traditional methods and this resulted in inconsistent data.
- Major problems faced during road inventory and condition survey were; inadequate funding, inadequate transportation and shortage of qualified manpower.
- There is no particular standard criteria adopted by AACRA for road maintenance prioritization purposes.
- Road maintenance activity plan was prepared by assessing quantities using AACRA'S own format and the ORF criteria to determine total cost of given maintenance activity.
- Tenders for consultancy service were evaluated based on the criteria set by ORF.
- Maintenance activities were conducted by their own force, not privatize

4.3 Problems encountered during the implementation of road maintenance management system

Effective Road maintenance keeps a road network and transport service operating. Increasing demand by road users will require continued construction and improvement of roads, in both urban and rural areas. Substantial economic benefits from road transportation cannot be sustained without adequate maintenance, which helps to keep a road network in a good condition, operating indefinitely with major deterioration over time and avoiding economic losses. Maintenance should be timely, preventing rather than curing significant road deterioration. Proper maintenance requires identification and prioritization, plan for maintenance activities, a trained work force with the required equipment's to carry out work, including money to pay for it. To have a proper and timely maintenance work, maintenance management system have to be properly established.

The current road maintenance management system in AACRA is very poor and it needs improvement; but, before proposing approaches for improving the system, the problems occurred during the implementation of road management system needs to be identified and fixed.

This analysis was conducted using interviews and questionnaire. The responses disclosed that there were many problems that occurred during implementation of road maintenance management processes and are described below:

i) **Inadequate budget**: In order to carry out appropriate maintenance interventions and preserve the road network to its original condition, sufficient budget need to be allocated. The Ethiopian Road Fund Office (ORF) is the only financier for maintenance works in Ethiopia .ORF had its own criteria for disbursement of the fund to road agencies.

According to the current practice, 65% of the revenue collected by ORF is allocated to ERA for the maintenance of the Federal road network; 25% is allocated to the regional road authorities for rural roads and 10% is allocated to the designated municipalities for the maintenance of city roads. Fifty percent (50%) of the Addis Ababa roads maintenance of activities are carried out by AACRA on The allocated budget for periodic and emergency maintenance by ORF since its establishment (1997/98 -2005/06) is presented in Table 4.11 below. The road network coverage of Addis Ababa was estimated at 5000 km (2016) and most of them require maintenance and the finding showed that AACRA faces budget constraints to carrying out the required maintenance activities. ORF has been able to finance 50% of what was required. Figure4.1 below illustrates the ORF disbursements graphically:

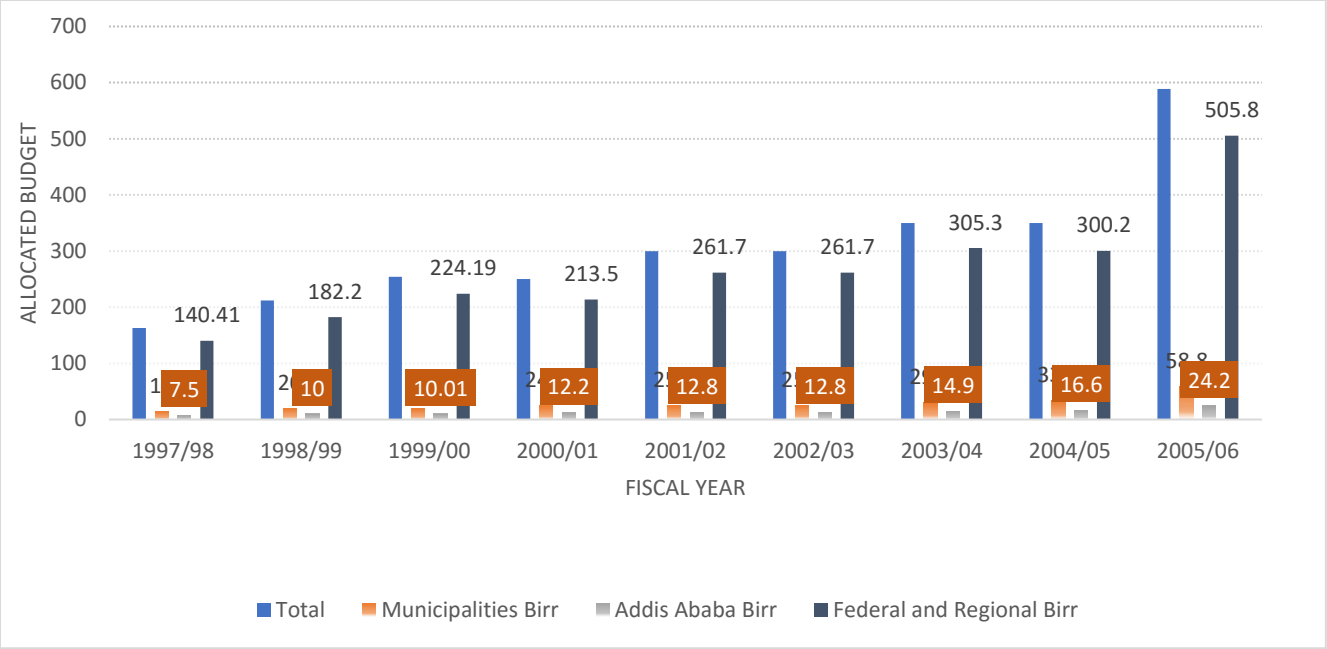


Figure 4.1 Road fund allocated budget

ii) **No database:** database are used to structurally organize and capture large quantities of data by inputting, storing, retrieving and managing information. In AACRA, the Snowy Mountains Engineering Corporation (SMEC) had developed a road maintenance management system with a good capacity database during 2004-2010 but failed due to considerable data requirements and lack of trained staff in AACRA and so the system was not able to be customized. Since then, there is no a well-established database in AACRA and thus, data were stored in hard copies in different computers of individuals who ever collected data. This makes difficult to obtain accurate and consistent data for planning and prioritization of roads. The findings during this research showed that there is no database for storing, retrieving and managing information in AACRA.

i) Traditional data inventory and survey method: in AACRA, road inventory and condition surveys have been carried out through visual inspection. During 2010-2015, road inventory and condition survey had not been properly carried out and because of that it was very difficult to obtain accurate data pertaining to AACRA. If road inventory data are not available, a road maintenance engineer cannot manage road works well, especially regarding planning. Similarly, road condition survey data is required for making intervention decisions. The

importance of these surveys cannot be ignored if maintenance works have to be managed well. Recently (2016/2017), AACRA tried to make improvements in data collection procedures. AACRA in collaboration with JICA tried to carry out road condition surveys using visual inspection support system consisting of smart phone application and GIS. In this tool, photo and location were automatically stored. Advanced data collection tools have to be applied to obtain persistent and consistent data that enables reliable long and short term planning.

ii) Lack of trained staff: well trained workers help increase productivity. Investing in employee training improves workers' retention rate, customer satisfaction and creativity. Training's should be provided continuously to develop the capacity of the staff and to introduce them with new technologies, ideas and methods. The findings from this research shows that in AACRA, staff trainings are not provided consistently as required to develop their capacity, making productivity enhancement very difficult.

The acquired data through the questionnaires were analyzed using the average Index Method and, frequencies for most and least ranked problems during the implementation of road maintenance were generated. The analysis was rigorously done based on the six major problems which are listed in the Table 4.13 below. Most respondents agree that the very problem regarding RMMS is "inadequate funding for maintenance activities", while the least the respondent agreed on was lack of a standard manual with guideline. In this regard, the calculated average index were 3.53 and 1.86 respectively. Figure4.2 below illustrates the list of problems encountered during implementation of maintenance management graphically:

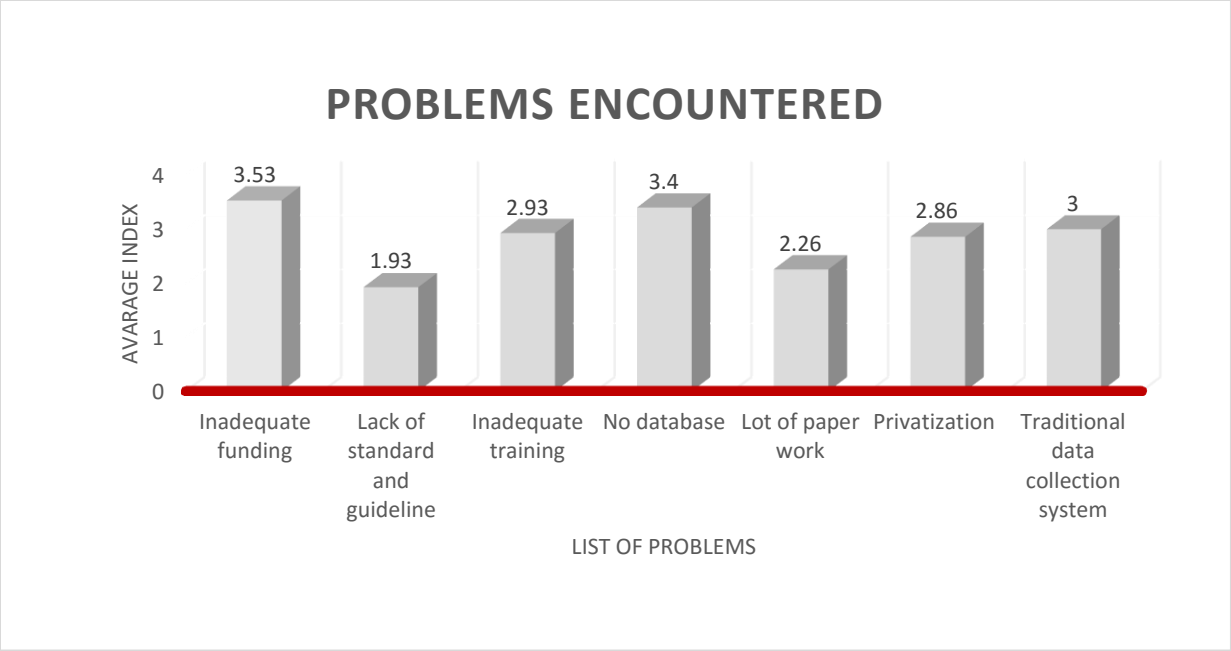


Figure 4.2 Road fund allocated budget

Generally, the findings shows that the majority of the respondents agreed on the major problems of road maintenance, the major ones being inadequate funding; while the least one was lack of standard manual and guide line.

It was therefore recommended that a computerized road maintenance management system be developed as a solution to the problems and weaknesses encountered in the current road maintenance management system

CHAPTER FIVE

SYSTEM DEVELOPMENT AND VALIDATION

5.1 Introduction

It was found that the current road maintenance management system of AACRA was ineffective. Without an effective road maintenance management system, the value of road network can be quickly eroded and road users and the society can experience a significant adverse impacts, if a road network is in a poor condition. The impact of proper road maintenance is significant; providing safety, economic development, environmental and social wellbeing. Therefore, the current road maintenance management system within AACRA has to be improved to make it more effective and user friendly.

To improve the current road maintenance management system, a computerized road maintenance management system was developed. The system development process comprises

- ✓ The design of each module
- ✓ Development of database
- ✓ Development of the system and validation with the collected data
- ✓ Performances and results of the system are also presented

5.2 Module design

Based on the current challenges faced and recommendations given templates were designed for each module.

5.2.1 Road Inventory

The designed road inventory module consists of two major parts. The first part deals about the general detail of the road condition such as:

i) **Road class**: for the design of this module AACRA road class classification system were considered as given below

Table 5.1 AACRA road class classification

Acronyms	Road Class	Standard width
RR	Ring Road	-
PAS0	Principal Arterial Streets 0	-
PAS1	Principal Arterial Streets 1	60 m
PAS2	Principal Arterial Streets 2	50 m
PAS3	Principal Arterial Streets 3	40 m
PAS4	Principal Arterial Streets 4	30 m
SAS1	Sub Arterial Streets 1	25 m
SAS2	Sub Arterial Streets 2	20 m
C	Collector Streets	15 m
L	Local Streets	10 11

ii) **Sub city and Wereda location**: 10 sub cities and each wereda in the sub city of Addis Ababa were considered for the design of the module these are;

- ✓ Addis Ketema sub city
- ✓ Akaki Kality,sub city
- ✓ Arada sub city
- ✓ Bole sub city
- ✓ Gullele sub city
- ✓ Lideta sub city
- ✓ Kirkos sub city
- ✓ KolfeKeanio sub city
- ✓ Nifias Silk lafto and
- ✓ Yeka subcity .

Every sub city contains maximum of 14wereda and each wereda are considered in the design of the module.

iii) **Carriageway Pavement type**: the pavement types considered in the design of the module are

- ✓ Asphalt pavement
- ✓ Surface treatment
- ✓ Cement concrete
- ✓ Cobbled
- ✓ Gravel
- ✓ Earth
- ✓ Under construction
- ✓ Planned for construction.

Road length, number of section (each section is 100 m length),Annual Rainfall ,start of chainage and end of chainage ,start location and end location, width of the road and number of lanes were also considered in the design of the module.

The second part deals about major structures found along side with the road such as bridges, culverts and road furniture like traffic signs and road barriers.

5.2.2 Road condition survey

A module was developed that enables to assess the condition of the road at given time. The designed road condition survey consists of: the general characteristics of the road, pavement type, and major distress types and quantity of the distress and pavement condition index.

For standardization purpose the scales of pavement condition index developed by (Annual international Condition Study Report) is used. The assessment scales are:

Table 5 2 pavement condition assessment scale

PCI Range	Pavement condition
85-100	Very good
65-85	Good
50-65	Fair
50-60	Poor
20-40	Very Poor

For the design of this module the major pavement distress types found in Addis Ababa city are Assessed and summarized as below:

- ✓ Pothole
- ✓ Rutting
- ✓ Crocodile cracking
- ✓ Raveling
- ✓ Corrugation
- ✓ Shoving asphalt
- ✓ Subsidence
- ✓ Lacy edge
- ✓ Low shoulder gravel
- ✓ Traverse cracking
- ✓ Bleeding
- ✓ Delamination and
- ✓ Longitudinal cracking

The location of each distress and the description of road conditions are also presented based on the pavement condition value.

5.2.3 Road prioritization

A Criterion for road prioritization was developed which considers technical, socio-economic factors and stakeholders priorities.

i) The technical factors considered included

- ✓ average traffic flow,
- ✓ pavement condition index land
- ✓ Deterioration rate.

ii) Socio-economic factors include

- ✓ Cost and benefit of maintenance,
- ✓ Economic potential centers and population served.

iii)Stakeholder's priority

For this module the priority criteria developed by AACRA is used. In this priority criteria roads are classified in to three phases based on their strategic importance. Some examples of road sections under these phases are:

Phase 1

- ✓ Ayer Tena to total
- ✓ Bole airport to Kality
- ✓ Lebu to mekanisa
- ✓ Mwegenagna to Bole air port
- ✓ Total To Torhailoch

Phase 2

- ✓ From Ethiopia hotel to national palace
- ✓ From Legahare toTeodros Sq
- ✓ From meskel Sq mebrate to post office
- ✓ From Anbasader theater to Zewditu
- ✓ From Arada Buld. To Municipality

Phase 3

- ✓ From Torhiloch to Saris Weintej
- ✓ From Areke fabrica to T/Himanot Sq
- ✓ From Parlamente building to Lipzing Sq (German School
- ✓ From Zerihun Building through Atlas hotel to WORBEC building
- ✓ From Gotera inter change to Wolo Sefer

Some of the data were primary and others were secondary. The stakeholders in the study area were issued with questionnaires to fill in their priorities of roads to be maintained. This is considered to promote the road maintenance ownership in the communities. To avoid any biasness from the stakeholders, the researcher scored in each category of the technical and socio-economic factors. Technical factors contributed 50%, socio-economic factors 30% and stakeholders' priority 20% giving a total of 100% for each road (these percentages for each factor were deduced from the questionnaires). After arriving at the total marks for each road, all the roads' scores were compared

and ranked to come up with a maintenance priority list. This ranking was used as a maintenance decision making tool.

5.2.4 Road Maintenance plan

A standard road maintenance plan module was designed that used to capture the quantities of all various activities like patching , overlay , drainage works, shaping, gravelling etc. This was used to record maintenance and improvement needs assessment on each of the prioritized roads. Quantities of each proposed activity were indicated against its chainage. The quantities of each activity were summed up and transferred to a bill of quantities table. Appropriate rates derived from the averages of each activity based on the unit rate developed under the Office of Road Fund in 1997 were used to multiply with the respective quantities to arrive at estimated costs for each activity and hence the total engineer's maintenance estimate. This estimated cost was used for planning purpose

5.3 UML use case diagram

As long as the Road Maintenance management system is a windows application, the system administrator (the system administrator is an employee of the AACRA) holds all rights in the process of adding and modifying the information of the system. These amendments include, adding, modifying and deleting Road Maintenance information such as, Road class, Surface type, distress Type, Road furniture and Major structures found along the road. Figure below shows the UML use case diagram for the system.

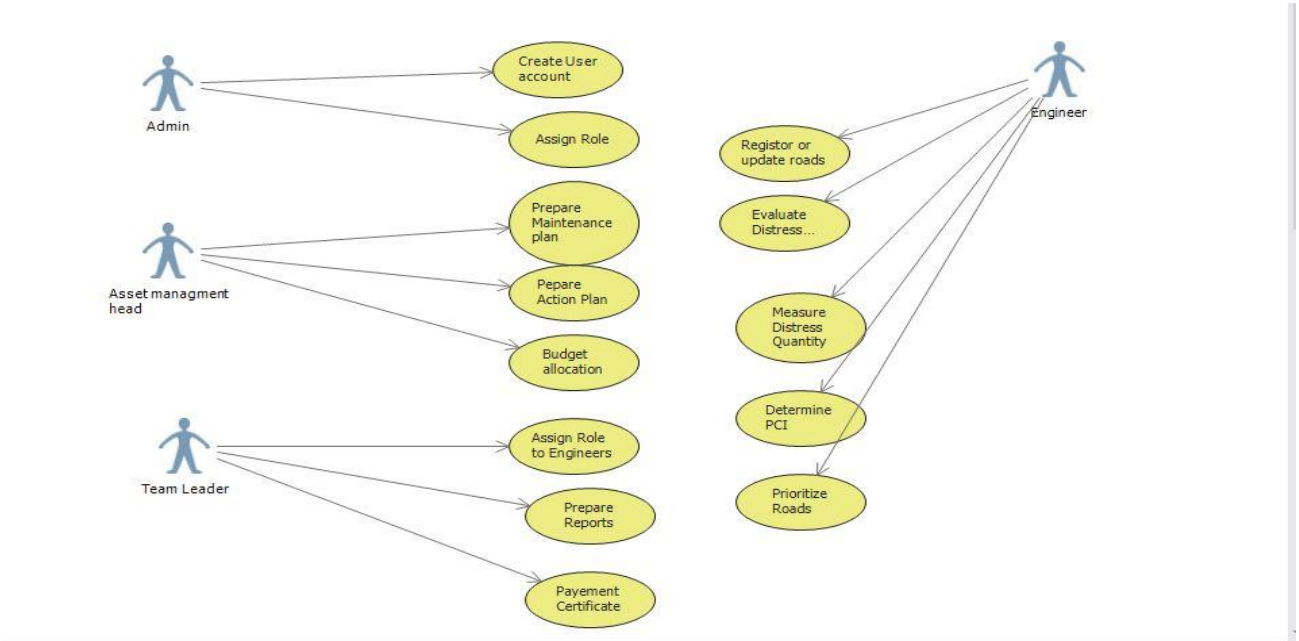


Figure 5.1 *UML case diagram*

5.4 UML Sequence diagram

It is an interaction diagram that shows how operations are carried out .They capture the interaction between objects in the context of a collaboration .sequence diagram are time focus and they show the order of the interaction visually by using the vertical axis of the diagram to represent time what message sent and when. The main purposes of sequence diagram are:

- ✓ Model high level interaction between active objects in the system
- ✓ Model the interaction between objects with in a collaboration that realizes an operation
- ✓ Either model generic interaction (showing all possible paths through the interaction) or specific instances of interaction (showing just one path the interaction)

The figure below shows a sequence diagram for making a road maintenance management system

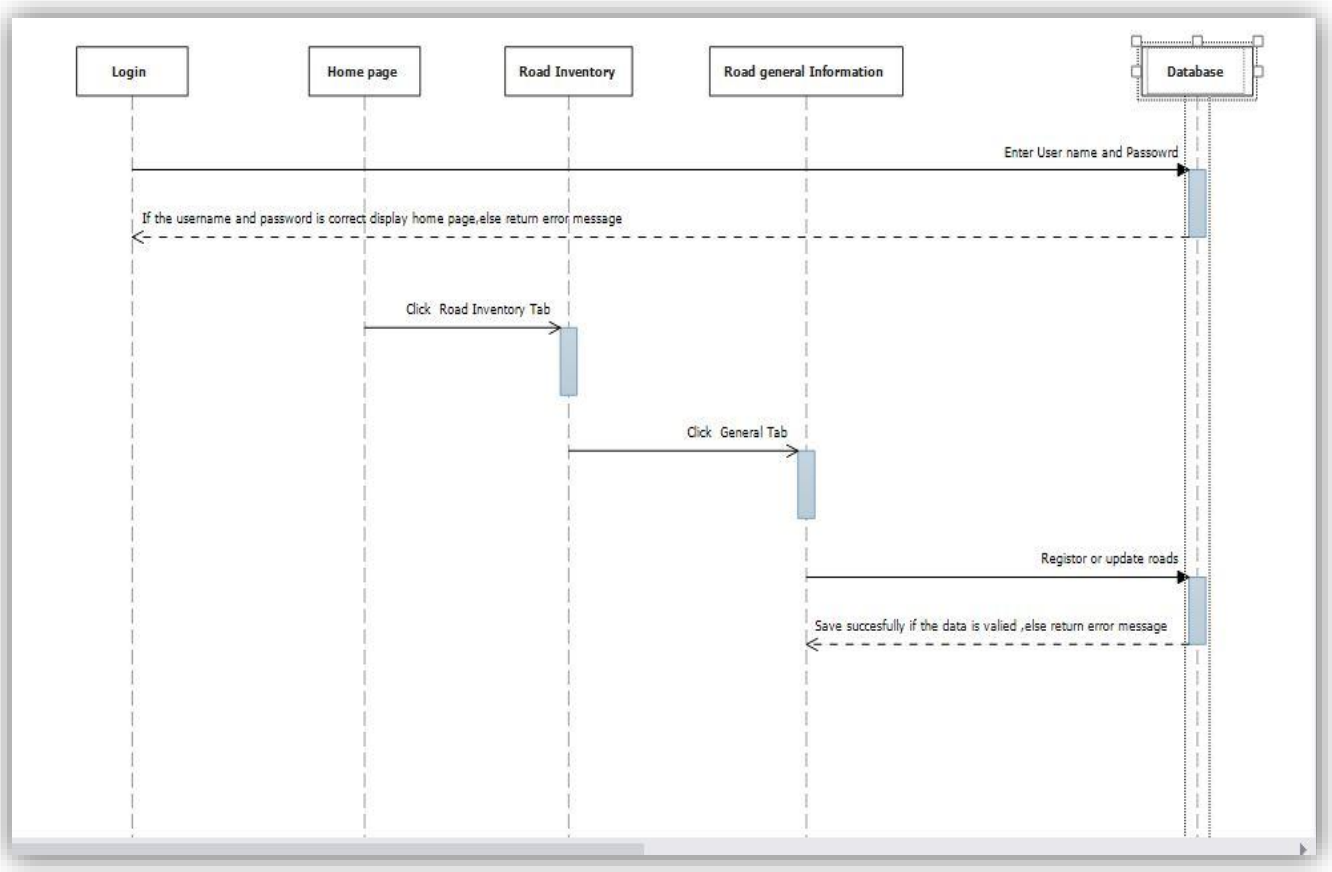


Figure 5.2 *General road information Sequence Diagram*

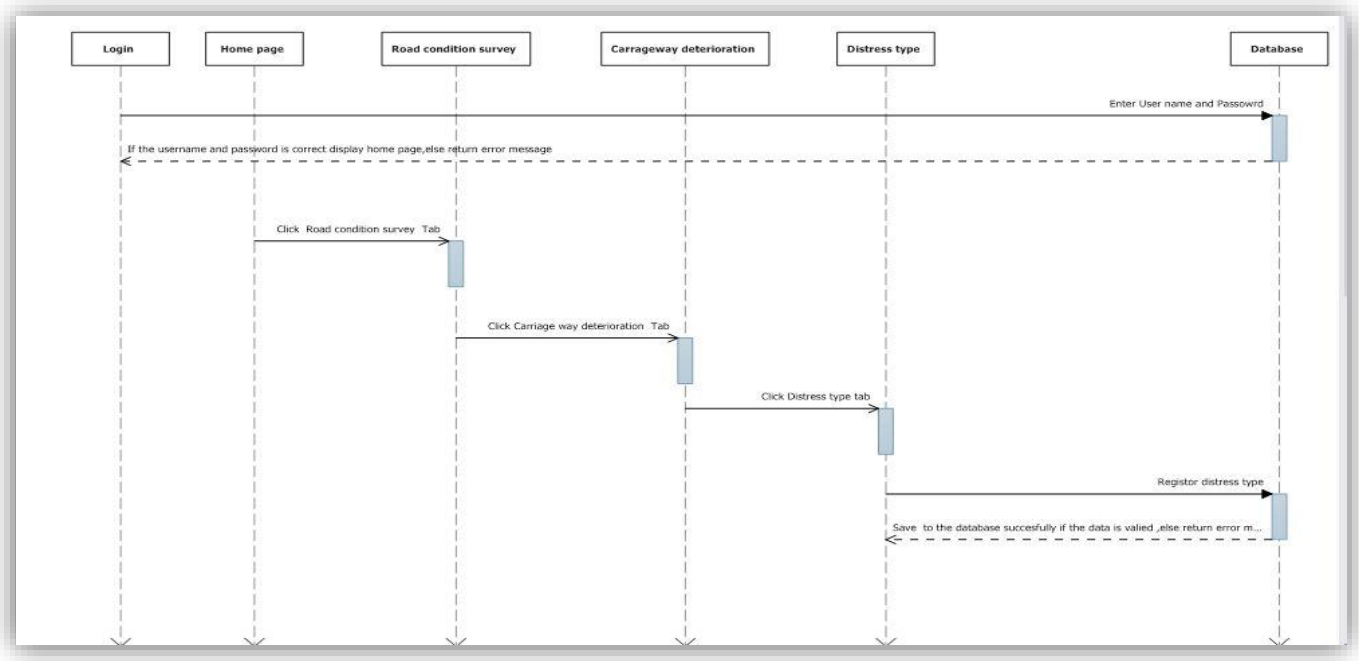


Figure 5.3 *Sequence Diagram for Distress type*

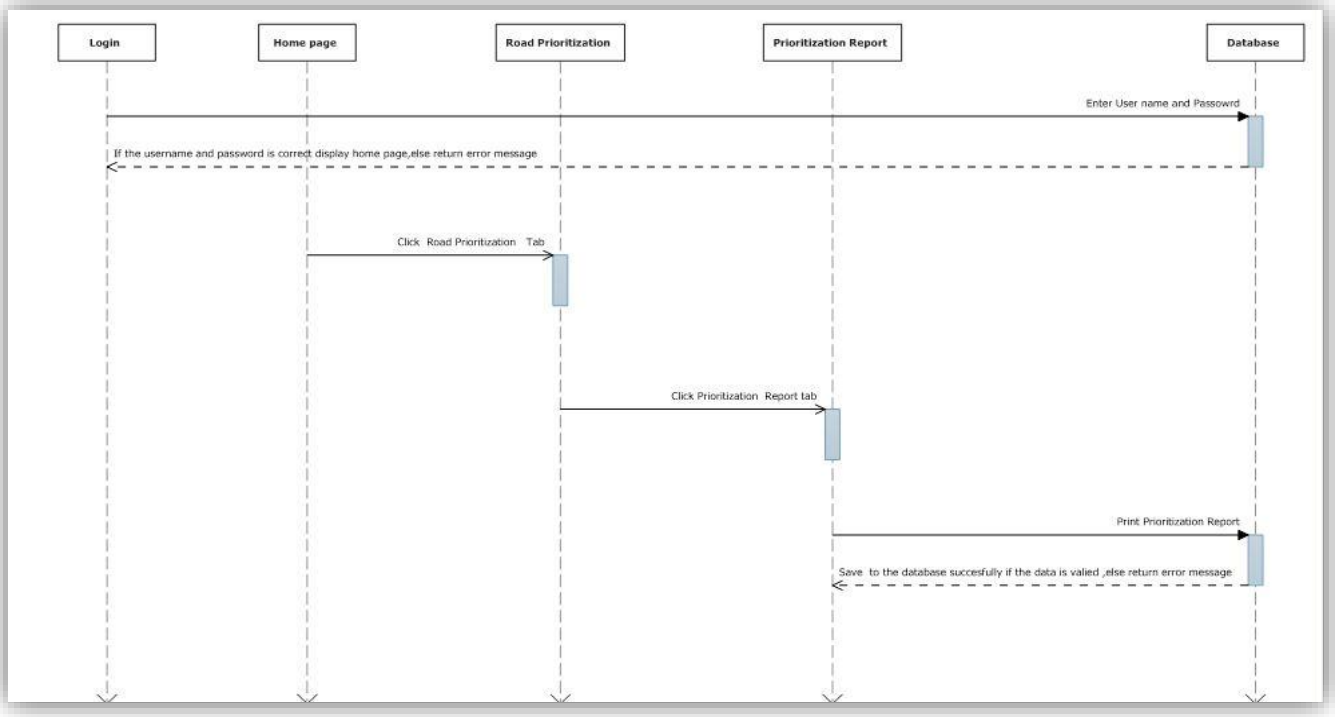


Figure 5.4 *Sequence Diagram for Prioritization Report*

5.5 Flow chart diagram

Based on the designed data forms, flowchart diagrams were designed for each of the modules.

Road Inventory and Condition Survey modules are used to illustrate this in figure below.

The process starts when the user enters data like general road information, surface type, Road furniture's on road inventory and data such as Distress type, quantity of distress and PCI on Road condition survey etc. The system then checks whether the data is valid and save successfully on the database and eliminates those who do not valid (using the 'No' path) and only allows the valid data to proceed through the 'yes' path.

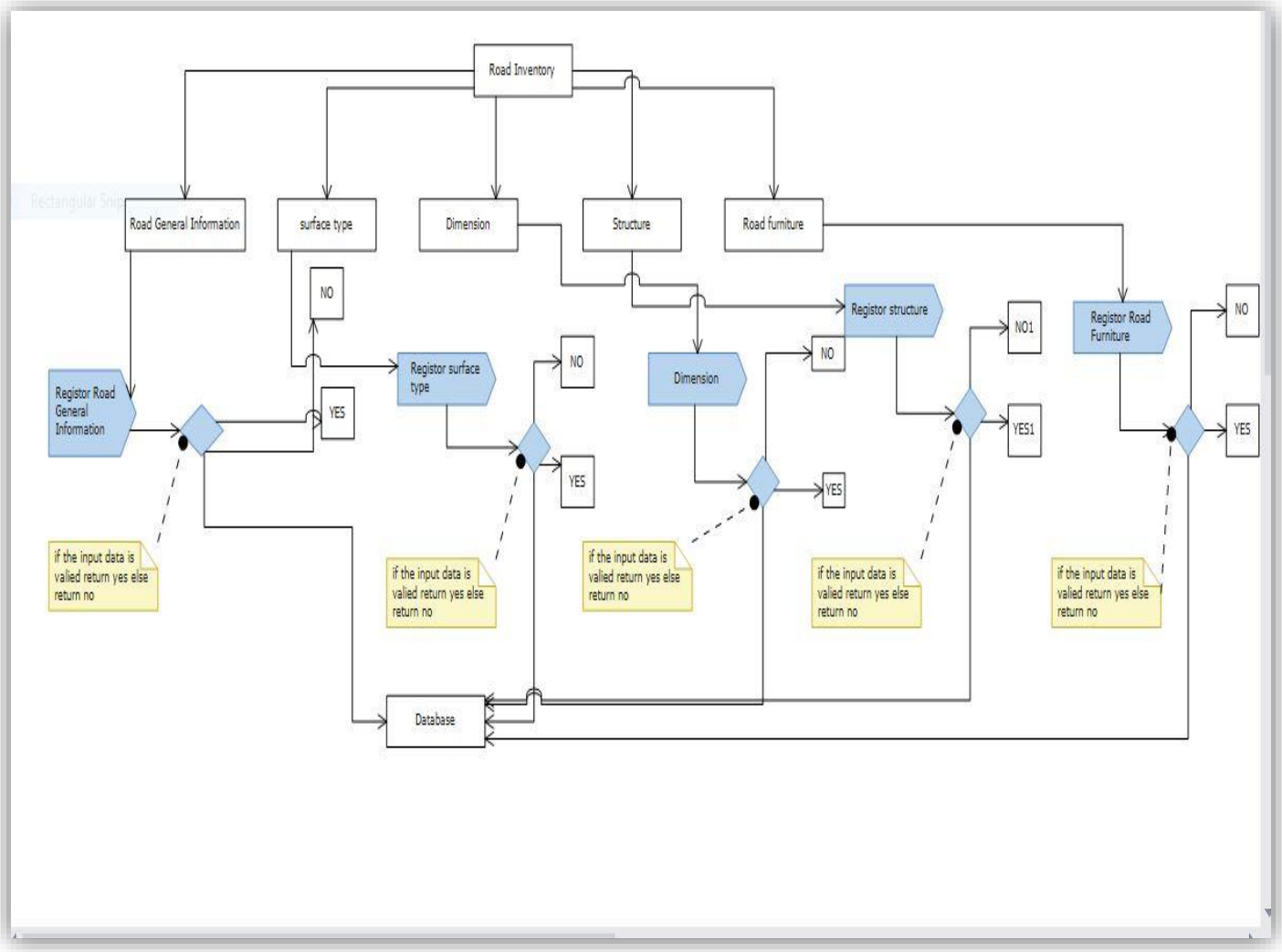


Figure 5.5 *Road Inventory flow chart Diagram*

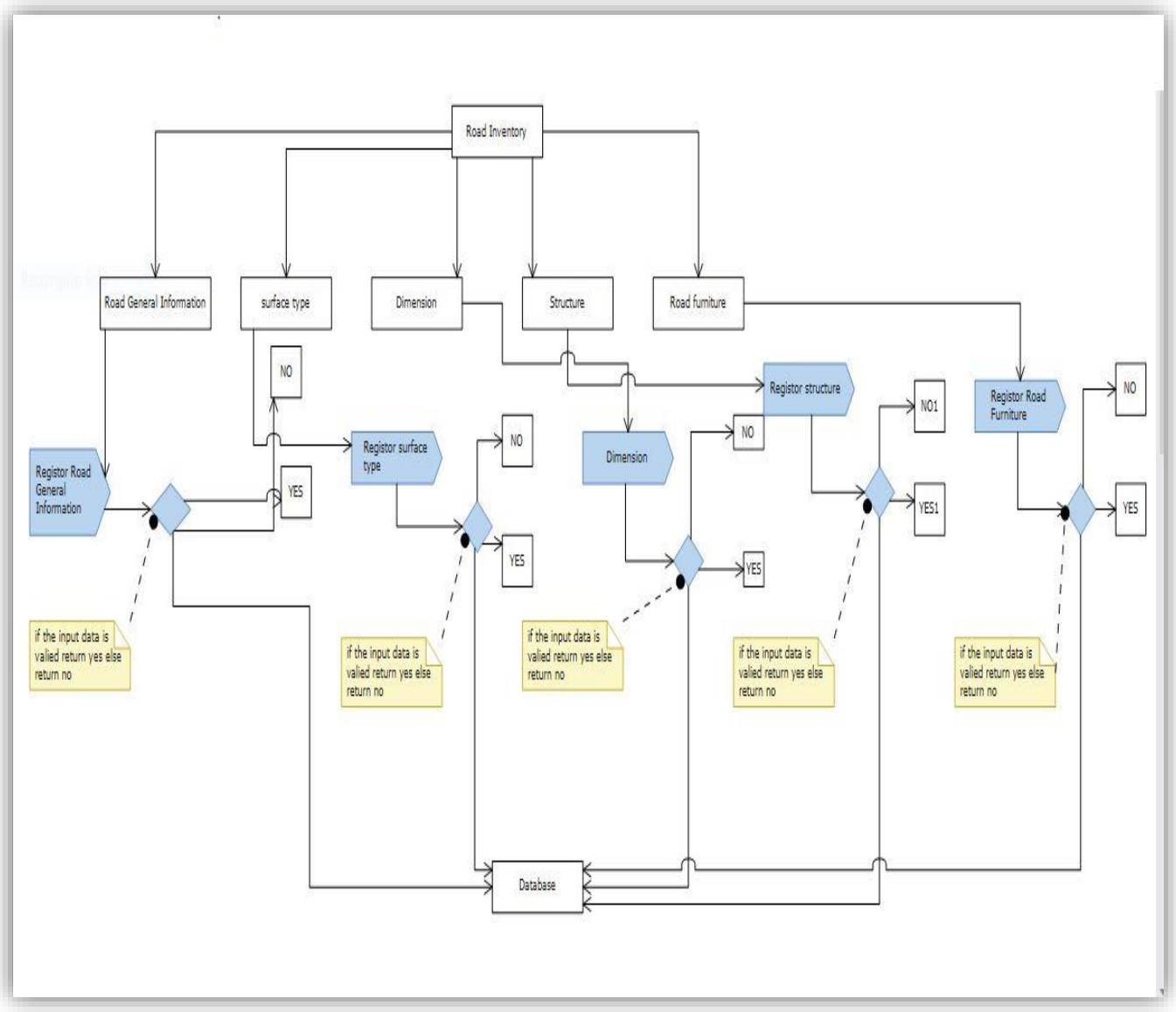


Figure 5.6 *Road Condition survey flow chart Diagram*

5.6 Data base design

A data base is a collection of information that is organized so that it can be easily accessed, managed and updated .Data is organized into rows, columns and tables, and it is indexed to make it easier to find relevant information. Data gets updated, expanded and delated as new information added .It processes workloads to create and update themselves, querying the data

they contain and running the applications against. To design the database Microsoft SQL Server 2014 is used. The figure below shows the main interface of the SQL server 20014 program.

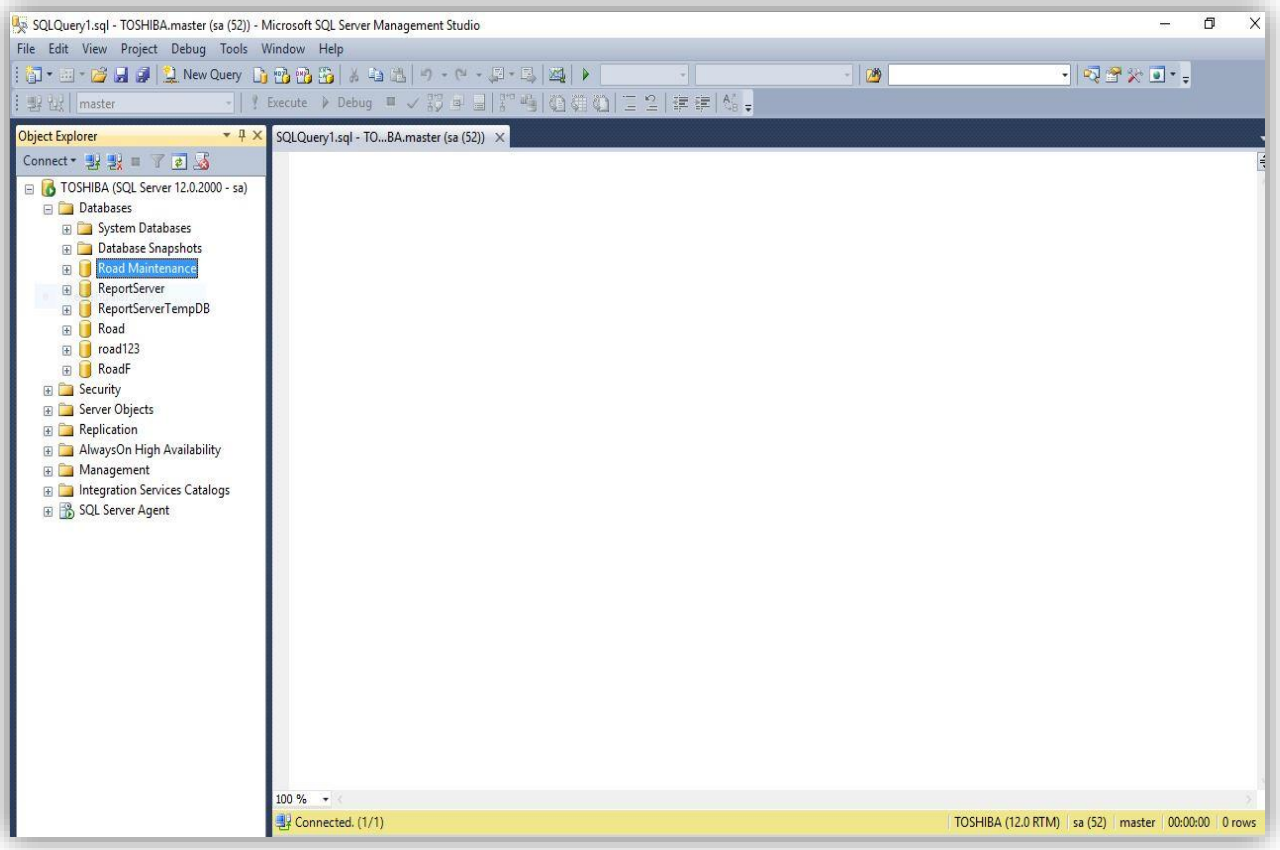


Figure 5.7 the main interface of the SQL server 2014 program

5.6.1Structured Query Language (SQL)

SQL is structured Query language, which is computer language for storing, manipulating and retrieving data stored in relational database. SQL is the standard language for relational Database system. A database language SQL allows users to

- ✓ To access data in relational database management system
- ✓ Describe the data
- ✓ To define the data in a database and manipulate that data
- ✓ To create and drop database and tables

- ✓ Create view, stored procedure, functions in a data base
- ✓ Set permissions on tables ,procedures and views

5.6.2 Components of SQL

The SQL standard has two major components

Data Definition Language (DDL): Language that allows the Data base administrator or user to describe and name the entities, attributes and relationships required for the applications together with any associated integrity and security constraints. DDL statements let to do these tasks:

- Create, alter and drop scheme objects
- Analyze information on tables, index, or cluster
- Establish auditing options
- Add comments to the data dictionary

Data Manipulation Language (DML): A language that provides a set of Operations to support the basic data manipulation operations on the data held in The database. Data Manipulation operations usually include the following: Insertion of new data into the database.

- Modification of data stored in the database.
- Retrieval of data contained in the database.
- Deletion of data from the database

5.6.3 Database Development Process

The database development process comprise the following steps

Step 1 - Create Database: From the Windows Start Menu, select "Microsoft SQL Server" and then "SQL Server Management Studio". Once the Management Studio starts, right click the Databases folder and select new database. Enter a name in the "Database name" text box. As shown in the Figure below.

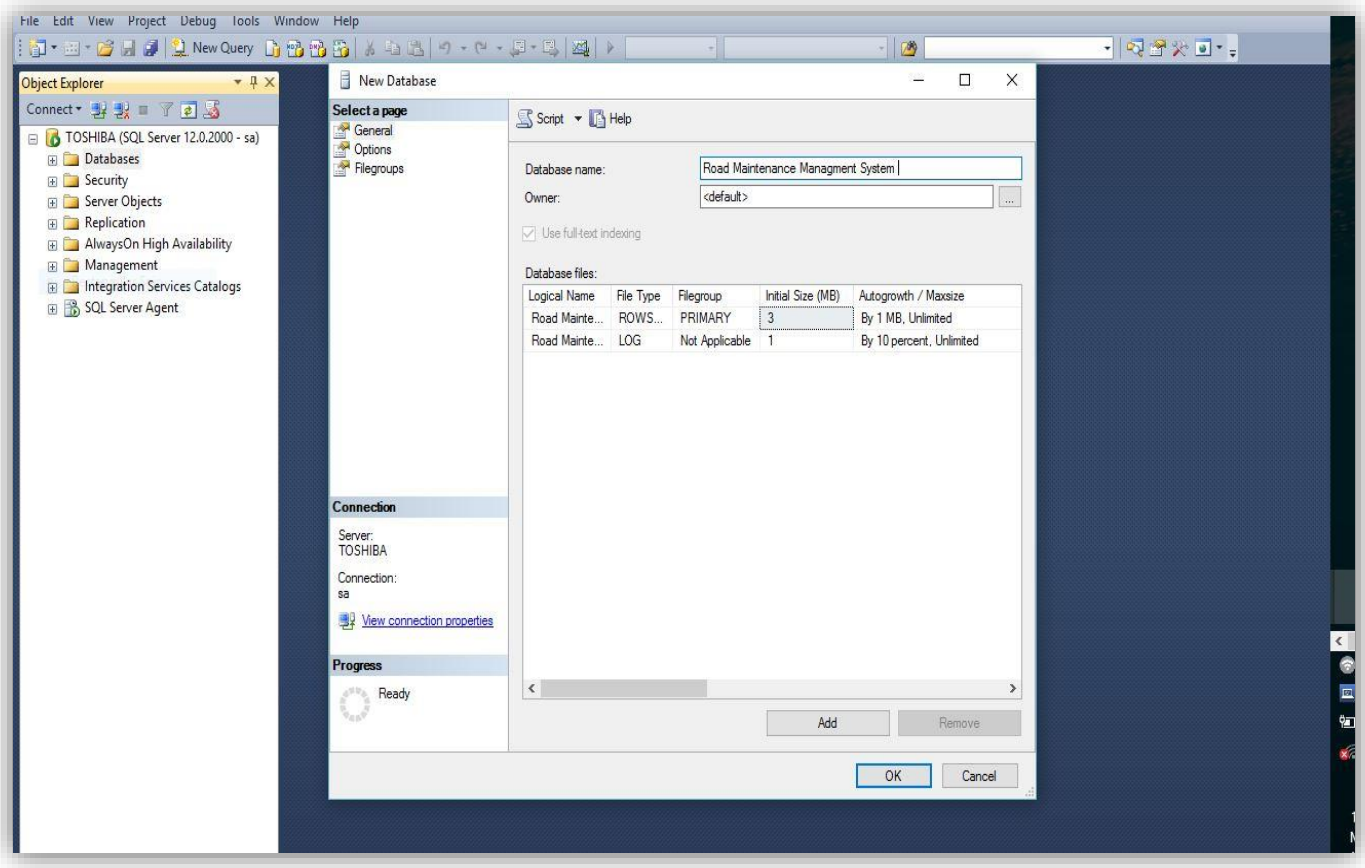


Figure 5.8 *Creating New Database*

Step 2 - Create a Table: A structure to hold the actual data is needed. This structure is called a table, to create a table, expand the database folder and then expand the newly created “Road Maintenance Management system” database as shown in figure below

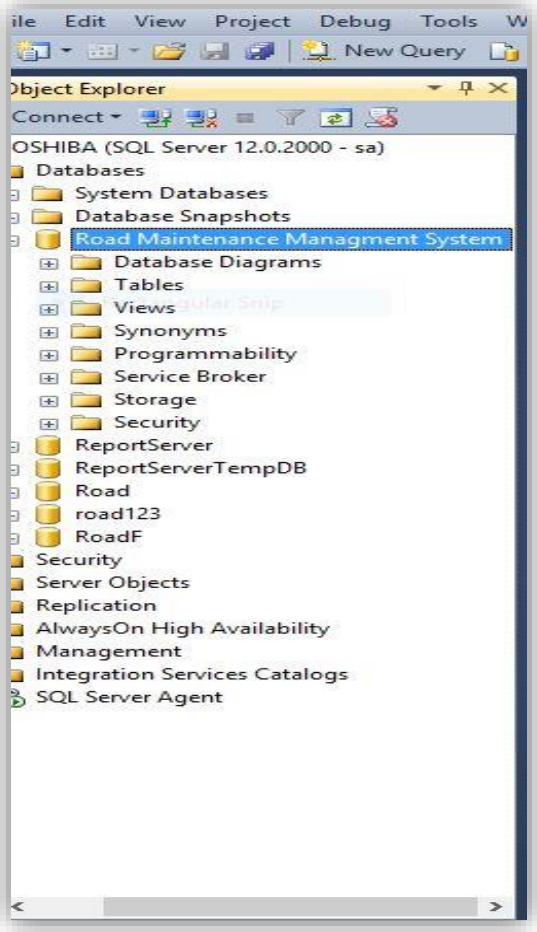


***Figure 5.9** creating a table for a new Database*

Now, right click on “Tables” and selecting “New Table”. Will be prompted to fill in “Column Name” and “Data Type”.

Step 3-Enter and View Data: To enter data into the newly created for example “Activity detail” table, expand the tables folder from the left menu as shown below:

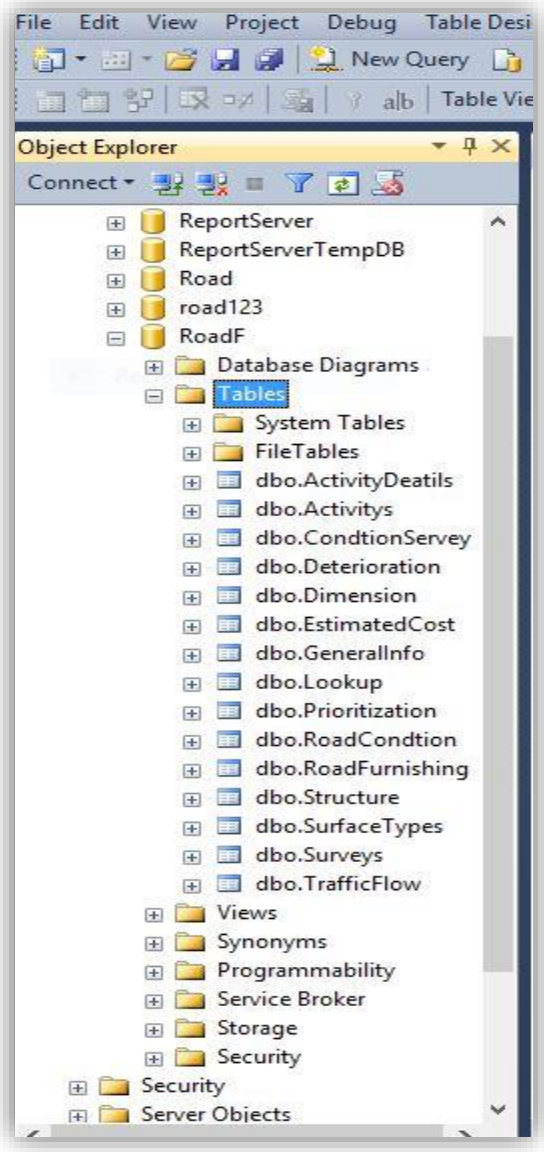


Figure 5.10 *creating a table for a new Database*

5.7Road Maintenance System Validation

The data were collected from a sample of four roads in Addis Ababa City Roads (AACRA) for validating the designed Road Maintenance Management System. For road inventory and condition survey secondary data were used for the general characteristics of the road. Data regarding to structures and road furniture were collected by driving through the road and stopping at the appropriate chainages. For road prioritization some data are primary data gathered from road while others are secondary data

collected from AACRA. Data for maintenance plan were gathered based on the proposed maintenance Activity.

5.7.1 System user dialogue steps

1. The user switches on the computer
2. Select road maintenance management system (RMMS)
3. The user login
4. The user enters the password
5. The system displays the modules
6. The system displays the data entry sheet
7. The user enters data and save
8. Repeat from step 5-7 for other modules
9. Select the print button
10. The system generates the required report

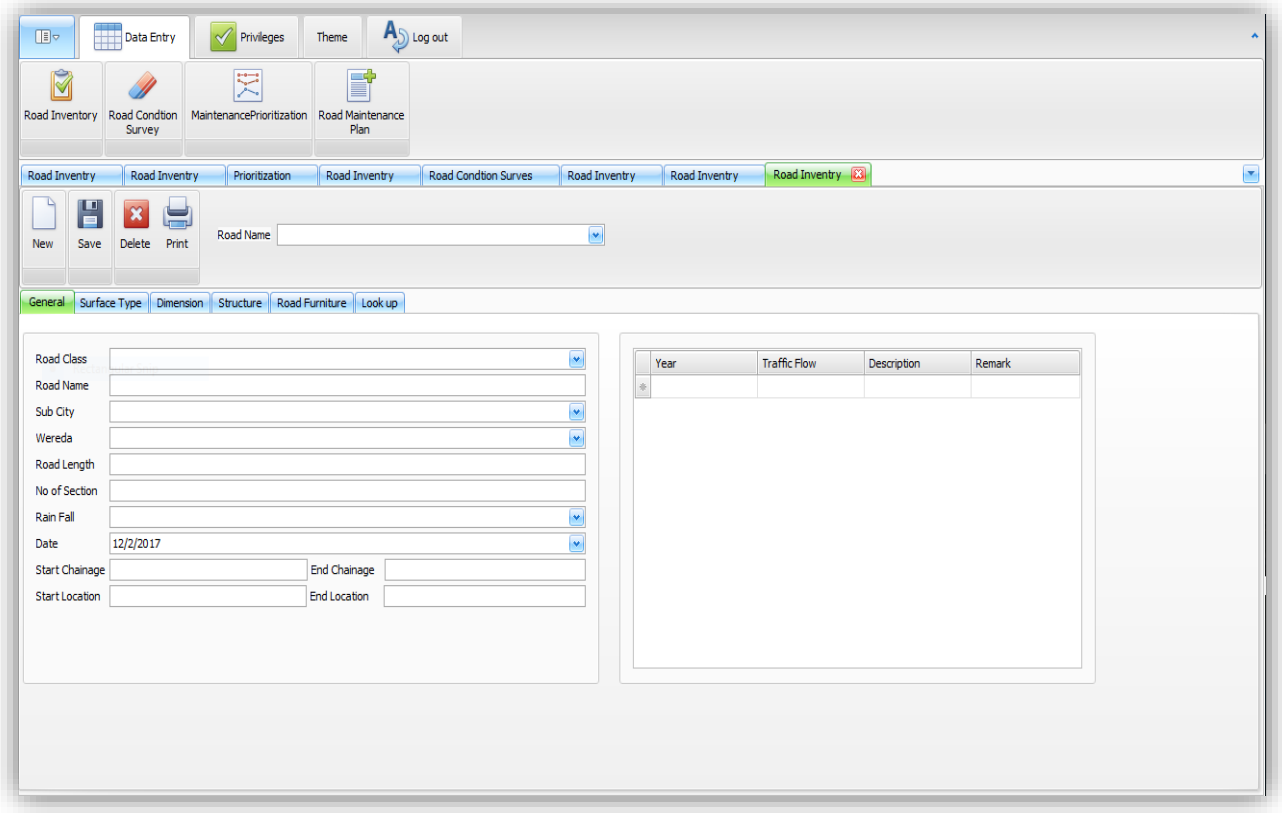


Figure 5.11 system home page

5.7.2 Road Inventory

The collected data on road inventory were entered in road inventory module. This data includes Road class, Road Name, Sub city and Wereda location, Road length, number of section, Annual Rainfall, start and end chainage, start and end location and average daily traffic. Major structures found along side with the road such as bridges, culverts and road furniture like traffic signs and road barriers. These details gave the general overview of the roads. Road inventory data entry window is shown in Figure below:

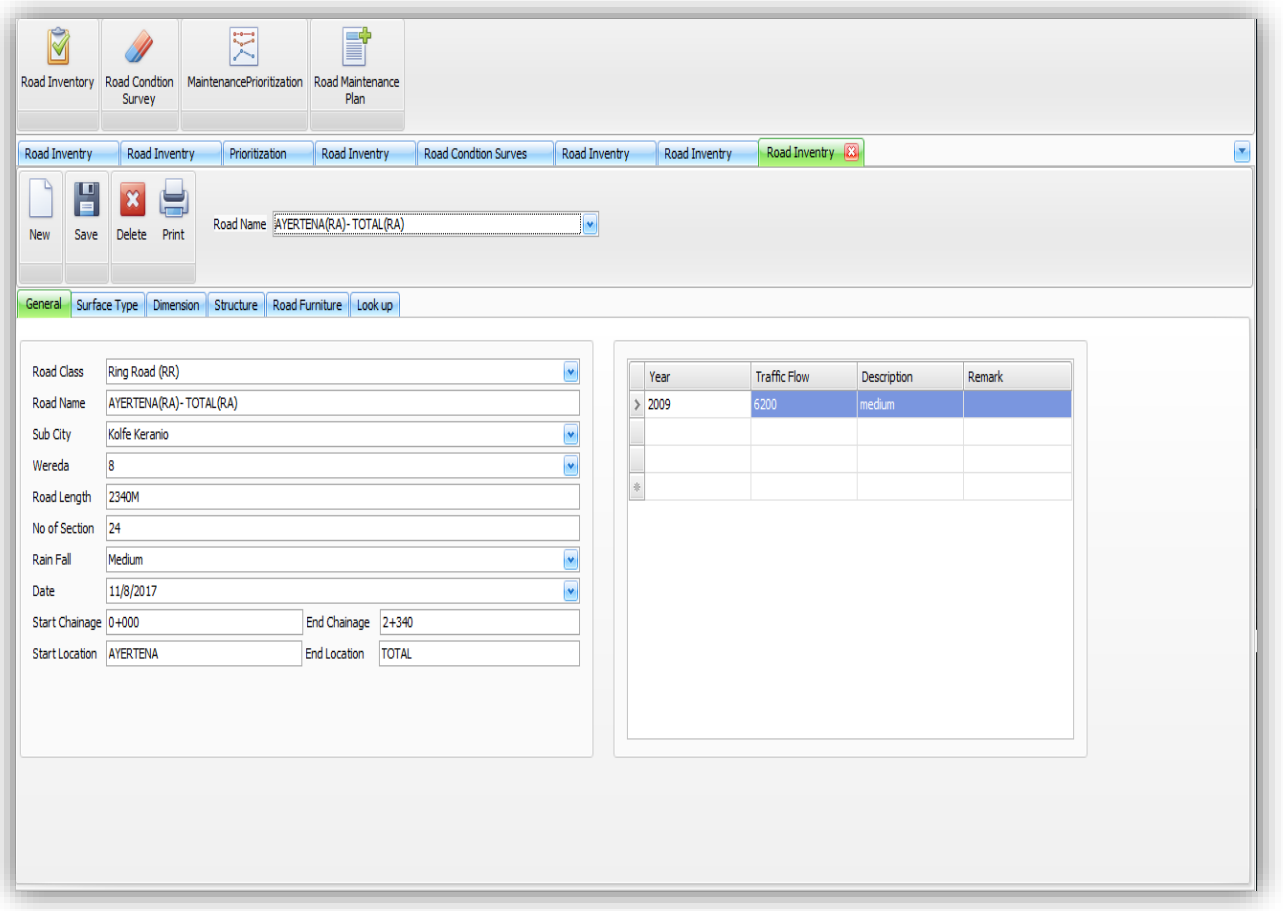
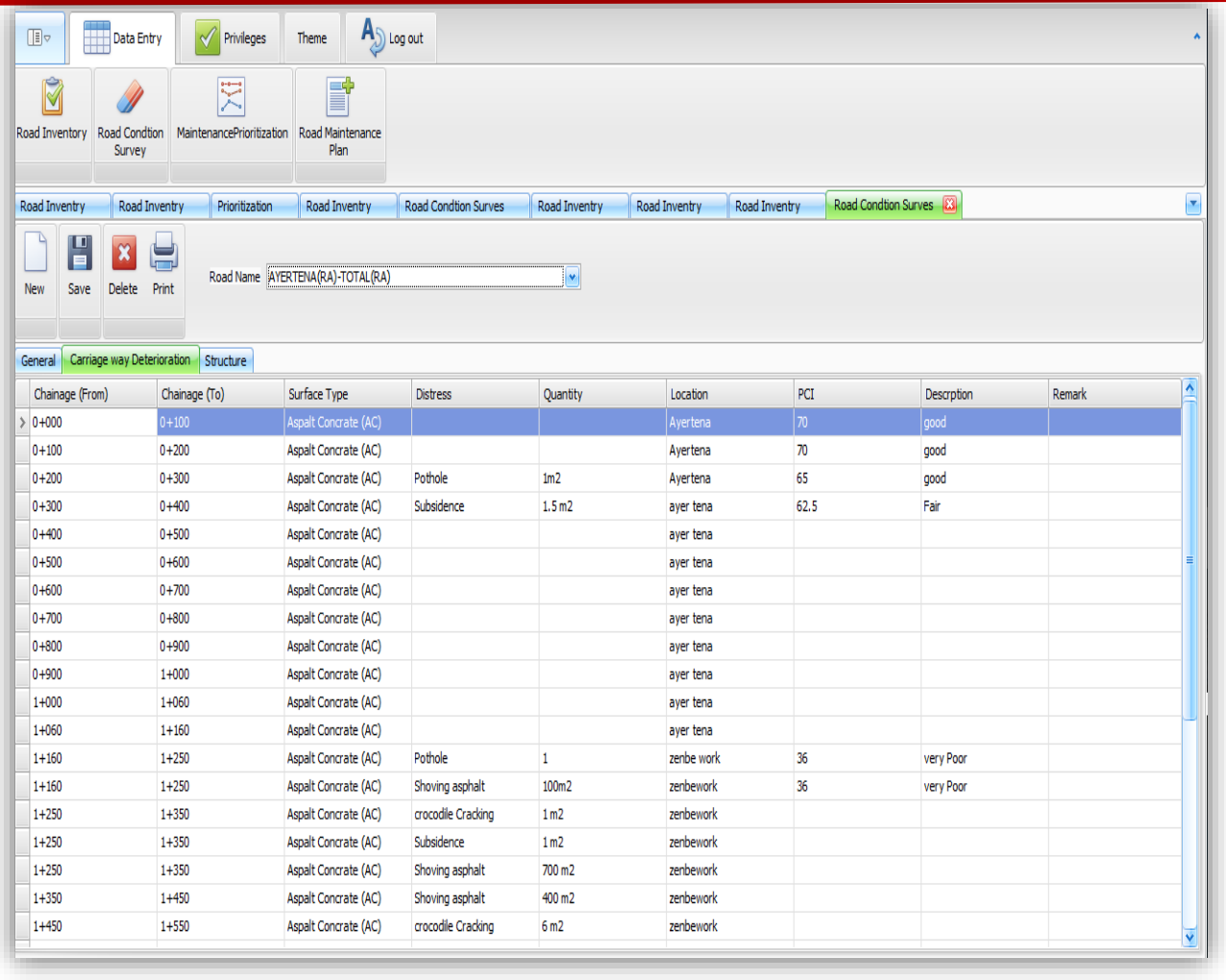


Figure 5.12 Road inventory data entry window

5.7.3Road condition survey

The collected data on road condition survey were entered in road condition survey module.this data includes the general characterstics of the road,carriageway deterioration (pavement type,distress type and quantity ,location of distress ,pavemeent condition index and description of pavement condition based on PCI value.conditon assesement also conducted for stuctures and entered in to the module.Road condition data entry window is shown in Figure below:



Chainage (From)	Chainage (To)	Surface Type	Distress	Quantity	Location	PCI	Descrption	Remark
0+000	0+100	Aspalt Concrate (AC)			Ayertena	70	good	
0+100	0+200	Aspalt Concrate (AC)			Ayertena	70	good	
0+200	0+300	Aspalt Concrate (AC)	Pothole	1m2	Ayertena	65	good	
0+300	0+400	Aspalt Concrate (AC)	Subsidence	1.5 m2	ayer tena	62.5	Fair	
0+400	0+500	Aspalt Concrate (AC)			ayer tena			
0+500	0+600	Aspalt Concrate (AC)			ayer tena			
0+600	0+700	Aspalt Concrate (AC)			ayer tena			
0+700	0+800	Aspalt Concrate (AC)			ayer tena			
0+800	0+900	Aspalt Concrate (AC)			ayer tena			
0+900	1+000	Aspalt Concrate (AC)			ayer tena			
1+000	1+060	Aspalt Concrate (AC)			ayer tena			
1+060	1+160	Aspalt Concrate (AC)			ayer tena			
1+160	1+250	Aspalt Concrate (AC)	Pothole	1	zenbe work	36	very Poor	
1+160	1+250	Aspalt Concrate (AC)	Shoving asphalt	100m2	zenbework	36	very Poor	
1+250	1+350	Aspalt Concrate (AC)	crocodile Cracking	1 m2	zenbework			
1+250	1+350	Aspalt Concrate (AC)	Subsidence	1 m2	zenbework			
1+250	1+350	Aspalt Concrate (AC)	Shoving asphalt	700 m2	zenbework			
1+350	1+450	Aspalt Concrate (AC)	Shoving asphalt	400 m2	zenbework			
1+450	1+550	Aspalt Concrate (AC)	crocodile Cracking	6 m2	zenbework			

Figure 5.13 road condition survey data entry window

5.7.4 Road Prioritization

The collected prioritization data were entered in the system for the four roads considered. These data were in three parts; technical factors, socio-economic factors and stakeholders priority. Using the order of marks as set out in the system's setup, the System summed up marks for each road and ranked the roads automatically and generated a priority list.

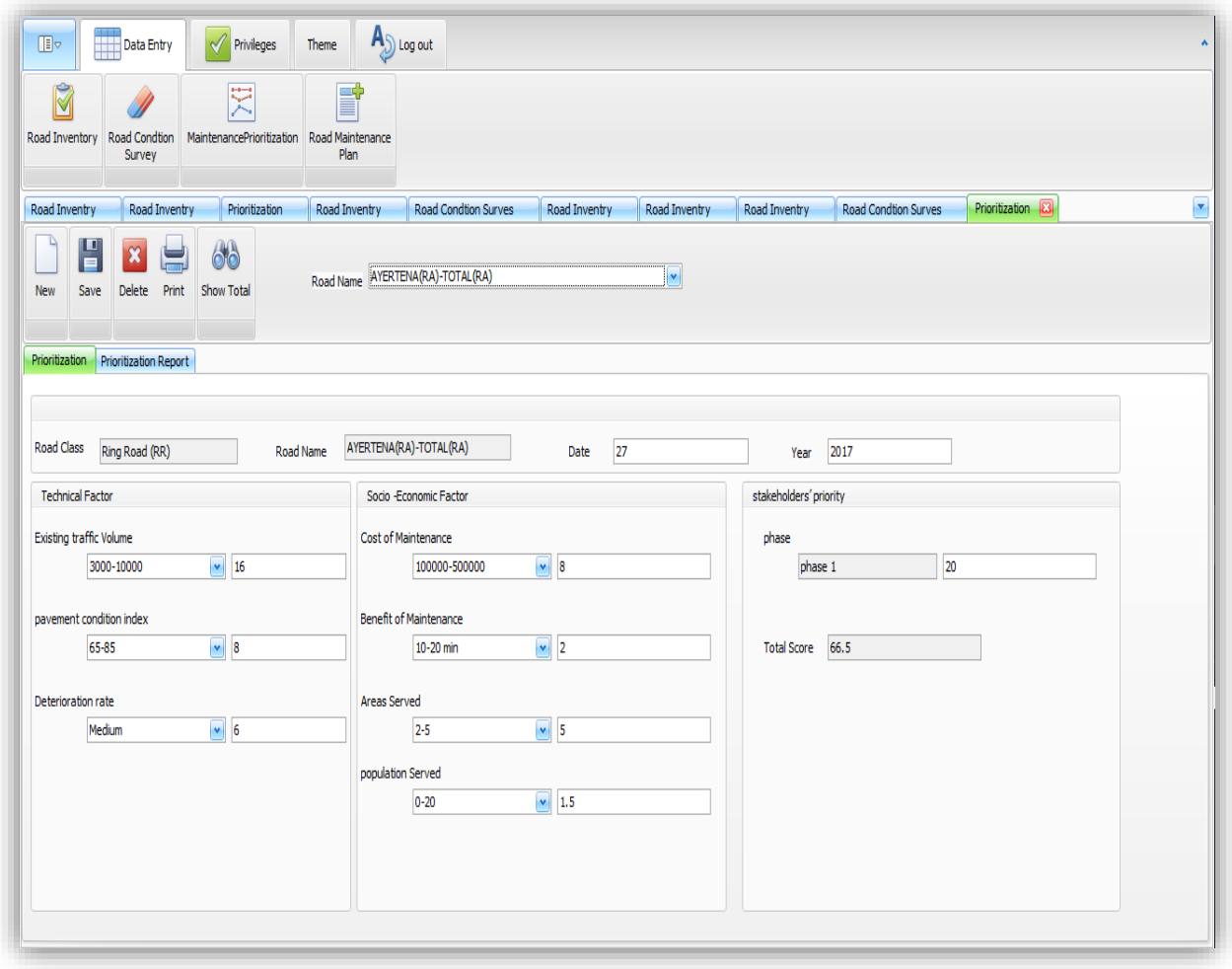


Figure 5.14 *Road maintenance prioritization data entry window*

5.7.3 Road Maintenance plan

Data collected from the field for road AYER TENA -TOTAL which was prioritized under the prioritization module was entered in the system to test this module. Quantities of patching were used and engineer's estimate rates as derived from Office of Road fund were entered and the system generated engineer's estimates in a bill of quantities table (refer to section 5.2.1.4). Road maintenance plan data entry window is shown in Figure below:

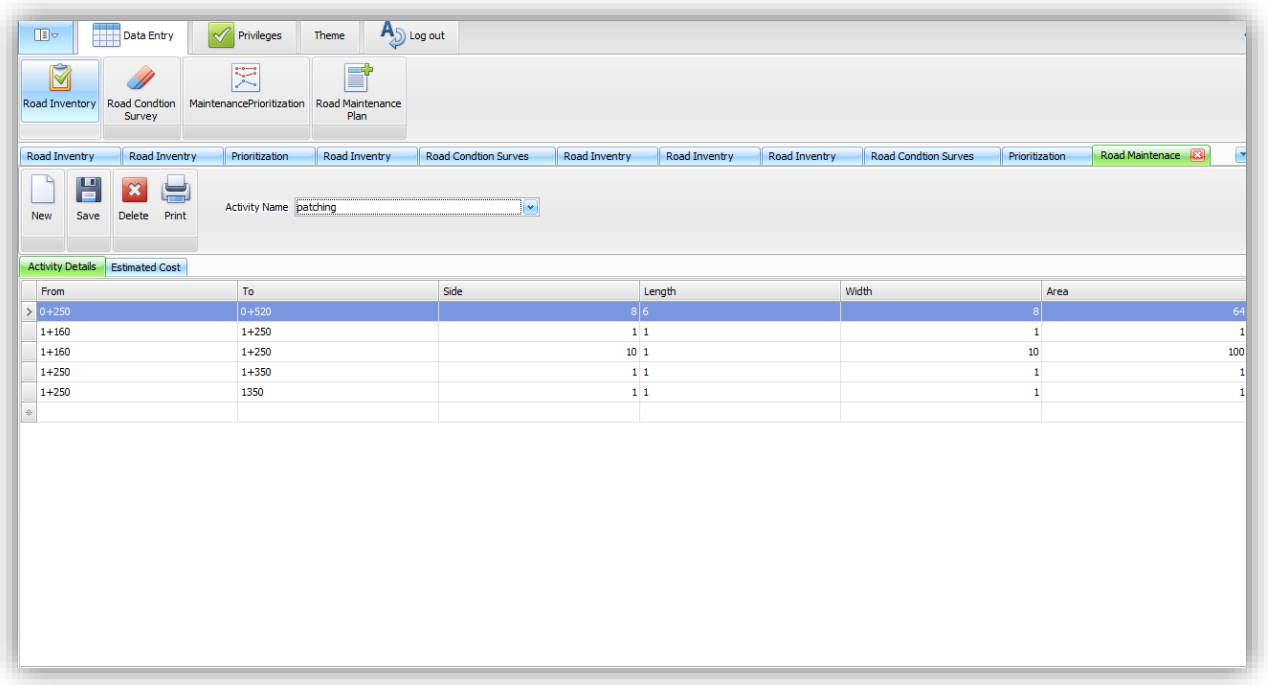


Figure 5.15 Road Maintenance plan data entry window

5.8System Performance and Validation Results

After developing of Rod Maintenance Management System, data collected from the AACRA and field for modules (road inventory, condition survey, prioritization and maintenance plan) were entered into the system. The performance of the system and the results of the tests are discussed

5.8.1 Road inventory

Road inventory survey was carried out for roads AYERTENA-TOTAL, TOTAL-TOREHAILOCH, LANCHA –GOTERA and FEDERAL COURT HOUSE/ST. LIDETA STATION- WEST-MEXICO. The system can generate road inventory survey report from the data entered for each of the roads. The table below shows road inventory output for AYERTENA-TOTAL road section.

Table 5.3 *Road inventory system generated report*

Saturday, December 2, 2017

Road Inventry

Road Class	Ring Road (RR)	Rain Fall	Medium
Road Name	AYERTENA(RA)- TOTAL(RA)	Start Chainial	0+000
Sub City	Kolfe Keranio	Start Location	AYERTENA
Wereda	8	End Chainial	2+340
Road Length	2340M	End Location	TOTAL
No of Section	24	Date	11/8/2017

Traffic Flow

Year	Traffic Flow	Description	Remark
2009	6200	medium	

Surface Types

Start Chainage	End Chainage	Surface Type	Remark
0+000	0+100	Aspalt Concrate (AC)	
0+100	0+200	Aspalt Concrate (AC)	
0+200	0+300	Aspalt Concrate (AC)	
0+300	0+400	Aspalt Concrate (AC)	
0+400	0+500	Aspalt Concrate (AC)	
0+500	0+600	Aspalt Concrate (AC)	
0+600	0+700	Aspalt Concrate (AC)	
0+700	0+800	Aspalt Concrate (AC)	
0+800	0+900	Aspalt Concrate (AC)	
0+900	0+1000	Aspalt Concrate (AC)	
0+1000	0+1100	Aspalt Concrate (AC)	

1+100	1+060	Aspalt Concrate (AC)	
1+060	1+160	Aspalt Concrate (AC)	
1+160	1+250	Aspalt Concrate (AC)	
1+250	1+350	Aspalt Concrate (AC)	
1+350	1+450	Aspalt Concrate (AC)	
1+450	1+550	Aspalt Concrate (AC)	
1+550	1+650	Aspalt Concrate (AC)	
1+650	1+750	Aspalt Concrate (AC)	
1+750	1+850	Aspalt Concrate (AC)	
1+850	1+950	Aspalt Concrate (AC)	
1+950	2+050	Aspalt Concrate (AC)	
2+050	2+150	Aspalt Concrate (AC)	
2+150	2+250	Aspalt Concrate (AC)	
2+250	2+340	Aspalt Concrate (AC)	

Dimension

From	To	Width	No of Lane	Remark
0+000	0+100	34	8	

Pages 1/2

Saturday, December 2, 2017

From	To	Width	No of Lane	Remark
0+100	0+200	34	8	
0+200	0+300	34	8	
0+300	0+400	34	8	
0+400	0+500	34	8	
0+500	0+600	34	8	
0+600	0+700	34	8	
0+700	0+800	34	8	
1+750	1+850	34	8	
1+850	1+950	34	8	
1+950	2+050	34	8	
2+050	2+150	34	8	
2+150	2+250	34	8	
2+250	2+340	34	8	

Structure

Chain Age	Description	Key Data	Remark
1+250	Bridge	Girder Bridge	waste materials are dumped and it ca

Road Furnitule

Chain Age	Description	Remark
0+070	Informative sign	Direction
0+170	Regulatory sign	Speed limit
0+650	Regulatory sign	Speed limit

The availability and quality of transportation data is a corner stone of any data-driven program there is continuous need to identify and develop alternative, reliable, and inexpensive sources of data. Road inventory data form the basis for any asset management of the road network .combining this inventory with regular assessment of its condition provides the basic justification for any road improvement and maintenance program. But in case of AACRA there is no well documented and organized road inventory data and data are not regularly entered and updated, this caused a lot of problems during planning process. The development of this computerized road maintenance management system, will improve the current practice in AACRA and enhances efficiency.

Various annual road inventory data such as road class, pavement type, number of lane, width of the carriage way, structures and road furniture can be stored and compared .this facilitated decision making process and saves a lot of time .The RMMS allows The roads data to be stored in a computer therefore it avoids a lot of paperwork and loss of information therefore increasing management efficiency.

5.4.3 Road Condition Survey:

Report was generated from the system showing summary of surface type, distress type, and quantity of distress, location of distress, pavement condition index and description of the road.

Table 5.4 Road condition survey system generated report

Saturday, December 2, 2017

Road Condition Surves

Road Class	Ring Road (RR)	Start Chainial	0+000
Road Name	AYERTENA(RA)-TOTAL(RA)	Start Location	AYERTENA
Sub City	Addis Ketema	End Chainial	2+340
Road Length	2340M	End Location	TOTAL
No of Section	24		

Carriage way Deterioation

Chainage (From)	Chainage (To)	Surface Type	Distress	Quantity	Location	PCI	Descrption	Remark
0+000	0+100	Aspalt Concrate			Ayertena	70	good	
0+100	0+200	Aspalt Concrate			Ayertena	70	good	
0+200	0+300	Aspalt Concrate	Pothole	1m2	Ayertena	65	good	
0+300	0+400	Aspalt Concrate	Subsidence	1.5 m2	ayer tena	62.5	Fair	
0+400	0+500	Aspalt Concrate			ayer tena			
0+500	0+600	Aspalt Concrate			ayer tena			
0+600	0+700	Aspalt Concrate			ayer tena			
0+700	0+800	Aspalt Concrate			ayer tena			
0+800	0+900	Aspalt Concrate			ayer tena			
0+900	1+000	Aspalt Concrate			ayer tena			
1+000	1+060	Aspalt Concrate			ayer tena			
1+060	1+160	Aspalt Concrate			ayer tena			
1+160	1+250	Aspalt Concrate	Pothole	1	zenbe work	36	very Poor	
1+160	1+250	Aspalt Concrate	Shoving asphalt	100m2	zenbework	36	very Poor	
1+250	1+350	Aspalt Concrate	crocodile Cradki	1 m2	zenbework			
1+250	1+350	Aspalt Concrate	Subsidence	1 m2	zenbework			
1+250	1+350	Aspalt Concrate	Shoving asphalt	700 m2	zenbework			
1+350	1+450	Aspalt Concrate	Shoving asphalt	400 m2	zenbework			
1+250	1+350	Aspalt Concrate	Shoving asphalt	700 m2	zenbework			
1+350	1+450	Aspalt Concrate	Shoving asphalt	400 m2	zenbework			
1+450	1+550	Aspalt Concrate	crocodile Cradki	6 m2	zenbework			
1+550	1+650	Aspalt Concrate	crocodile Cradki	12 m2	zenbework			
1+550	1+650	Aspalt Concrate	Raveling	240 m2	zenbework			
1+650	1+750	Aspalt Concrate	Pothole	0.25 m2	zenbework			
1+750	1+850	Aspalt Concrate	Raveling	160 m2	Total (3 Mazori			
1+850	1+950	Aspalt Concrate			Total (3 Mazori			
1+950	2+050	Aspalt Concrate			Total (3 Mazori			
2+050	2+150	Aspalt Concrate	Pothole	0.25 m2	Total (3 Mazori			
2+050	2+150	Aspalt Concrate	Rutting	160 m2	Total (3 Mazori			
2+150	2+250	Aspalt Concrate			Total (3 Mazori			
2+250	2+340	Aspalt Concrate			Total (3 Mazori			

Dimension

Survey	Location	PCI	Description	Remark

Structure

Chainage	Description	Key Data	Remark
1+250	bridge	girder bridge	

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A road maintenance engineer can use the conditions survey as one of the factors to make decisions on what road to maintain before the other and can compare the condition of a road with the previous year's conditions and therefore be in a position to tell if there is improvement in his network or not. A condition survey data are used as basis for every decision made with in RMMS .if the condition survey data are not reliable, none of the recommendations of the system are reliable. The intention of condition survey is to produce quantifiable and comparable data set to identify the condition of the road network as (very good, good, fair, poor and very poor) .the pavement condition index determines how bad the selected item or part of the road and determines the quantity of distress. The road condition survey is used in the next module of the system as a factor in prioritizing roads for maintenance in a given network**.**

5.4.4Road prioritization

A prioritization report was generated from the system for the four roads considered for system validation and calibration. The prioritization criteria considers the technical factor, socio-economic factor and stakeholder's priority for prioritization of roads. The system combined the total marks for all factors and automatically ranked the roads. Rank 1 means that road has the highest priority for maintenance. In this system once the roads data are entered the system can automatically prioritize the roads without any external influence. Therefore, this will improve the current prioritization practice in AACRA in which there is no clear criteria for road maintenance prioritization. It will ensure that road maintenance funds are used on the most deserving roads. It will support the AACRA roads management engineers in making maintenance decisions and it reduce political influence on road maintenance prioritization.

Table 5.5*Road prioritization system generated report*

Saturday, December 2, 2017

Prioritization Report

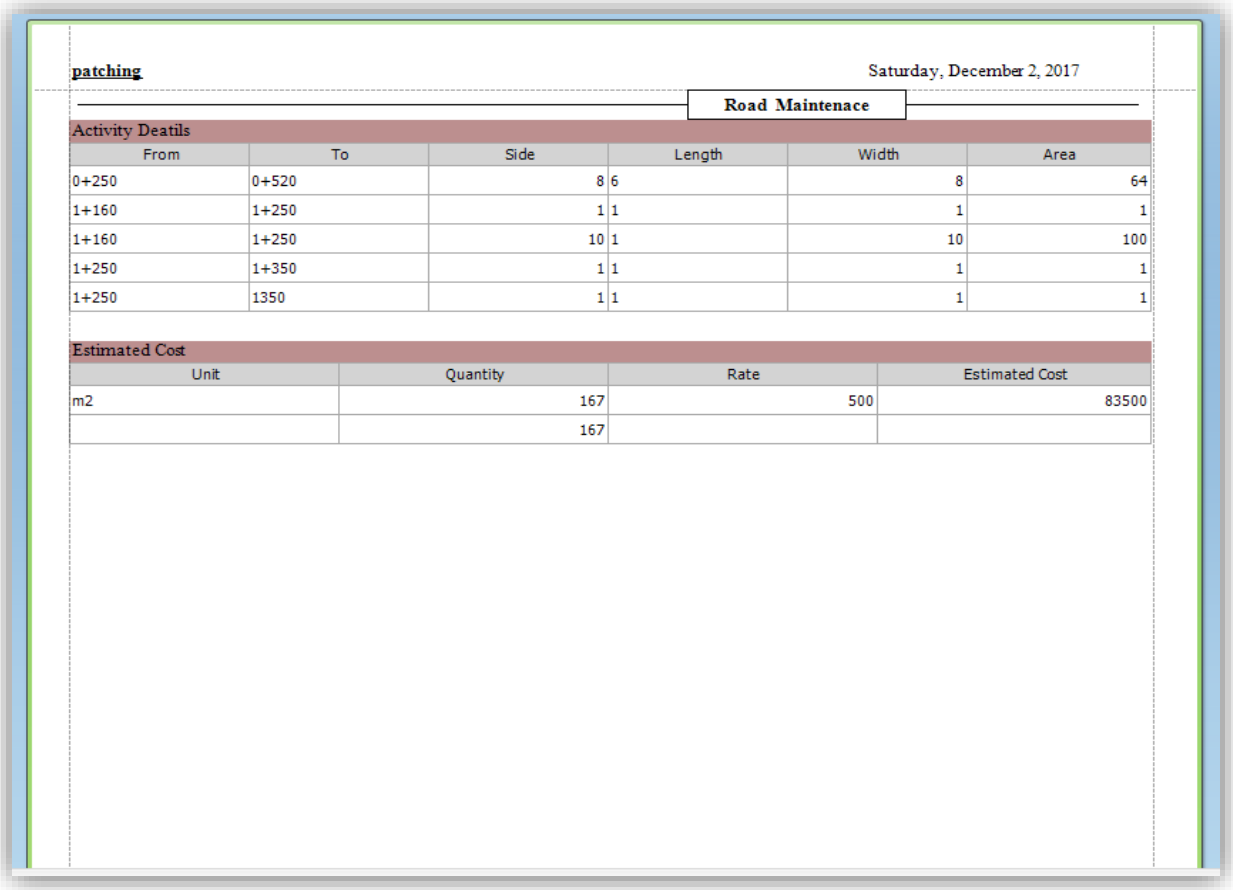
Road No	Road Name	Road Class	Technical Score	Socio EconomicScore	)vernmental InfluenceScc	Total Score	Ranking
RCO000000006	TOTAL-TOREHAILOCH		34	14.5	20	68.5	1
RCO000000007	LANCHA-GOTERA	Principal Arterial Streets	34	16.5	12	62.5	2
RCO000000008	Federal Court House/St.	Principal Arterial Streets	34	16.5	12	62.5	3
RCO000000006	TOTAL-TOREHAILOCH		36	18	20	54	4
RCO000000004	AYERTENA(RA)-TOTAL(	Ring Road (RR)	30	16.5	20	46.5	5

Table 5.

5.4.5 Road Maintenance plan

Road maintenance plan report was generated for the data entered for road AYERTENA-TOTAL as shown in Table below. This report detailed the Activity name, description, quantities, and rates and estimated cost of each activity.

__Table 5.6__ Road Maintenance plan system generated report



patching Saturday, December 2, 2017

Road Maintenace

Activity Deatils

From	To	Side	Length	Width	Area
0+250	0+520	8	6	8	64
1+160	1+250	1	1	1	1
1+160	1+250	10	1	10	100
1+250	1+350	1	1	1	1
1+250	1350	1	1	1	1

Estimated Cost

Unit	Quantity	Rate	Estimated Cost
m2	167	500	83500
	167		

5.5 Benefits of Road Maintenance Management system

The RMMS developed in this study can be used to make maintenance decision for Addis Ababa Roads, reduce corruption and to increase management efficiency among others.

5.5.1Decision support

To achieve the goal of building and maintaining a cost effective and reliable road system ,current pavement conditions, future maintenance needs ,anticipated new construction and estimated financial resources are blended with historical conditions ,and construction and maintenance activities in to decision –making system designed to assist engineers and planers in using and maintaining roads. Typically when this computerized road maintenance management system implemented, it can be an invaluable tool in deciding where and when pavement construction, maintenance, and rehabilitation efforts should occur.

The system can be used as a decision making tool; for example, in deciding which roads to maintain, the road prioritization module which also considers road condition as a factor is used. By using this system, political factors which often interfere with road maintenance prioritization decisions would be reduced and the maintenance engineers can always have supporting documentation on how they arrived at their decisions.

5.5.2 Increasing Efficiency

The system increases maintenance efficiency in a number of ways.

1.At the road inventory stage, the system stores all the road inventory information for use under all the other modules and are available to users anytime under one unit. This reduces the paperwork and time required in looking for information from hard material hence increasing efficiency and being economical.

2. Road condition survey information can be stored in the system and updated every year. This information will assist the maintenance engineer in monitoring the changes in road conditions. The road conditions are also as a guide in making maintenance intervention decisions.

3. The road prioritization process helps in coming up with road maintenance prioritization decisions which are documented and based on standard criteria.

4. Road maintenance plans help maintenance engineers in deriving quantities for preparation of tender documents.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

5.1 General

The main objective of the research was to assess the current road maintenance management system, to identify the weaknesses and the challenges faced during implementation of road management system and make recommendations based on the findings. In view of the above, the following conclusions and recommendations are therefore presented.

5.2 Conclusions

The following conclusions were developed based on the findings of the study:

- The study indicated that road inventory and condition survey were not appropriately conducted, no defend schedule for conducting road inventory and condition survey. Since road inventory and condition survey were not appropriately conducted, it was very difficult to have reliable and consistent data for planning purposes.
- The major problems faced during the carrying out of road inventory and condition surveys were inadequate funding, inadequate transportation and human resource.
- There is no clear particular criteria followed for prioritization of road for maintenance activities. The method used is subjective that is roads were prioritized through discussion with higher AACRA officials without following standards and criteria. So, funds are not appropriately utilized.
- Consultants were hired by AACRA on behalf of ORF for a year, and it was found that the duration was short to have a long term plan.
- The study identifies that inadequate funding (budget) is the major challenges faced during implementation of road maintenance management system in AACRA. There is no well-established database; hence, data were stored in hard copies without structurally organized. Maintenance activities were not privatized, both the client and the contractor is AACRA and it causes lack of accountability and quality is compromised. Data were collected using traditional method and this results in inconsistent data for planning and prioritization. Generally, the current road maintenance management system in AACRA was found traditional, ineffective and so quality is compromised

- The developed computerized Road Maintenance Management system was found efficient in number of ways for example: It reduce the amount of paper work, saves time, use standard criteria and clear guideline for road maintenance prioritization, reduce the amount of man power required for maintenance management, it can be used as useful decision tool, reduce corruption and increase the management efficiency.

5.3 Recommendations

Based on the findings of the study, the following recommendations are forwarded for the improvement of the current road maintenance management practice in AACRA.

- Advanced data collection tools such as, pavement condition survey with appropriate vehicles have to be incorporated soon, so that Quality Management could be integrated at all stages in pavement condition surveys to ensure accurate information that has to be provided to the management for decision purposes..
- ORF is the sole financer of road maintenance activities and can provide only 50% of what is required for road maintenance activities. Therefore, AACRA have to find a mechanism of securing more funds for consistent and sustainable maintenance of roads. AACRA also have to focus on conducting preventive maintenance for pavements before they deteriorate into unrecoverable conditions. This can save a considerable amount of pavement maintenance budget.
- It is recommended that AACRA have to implement computerized road maintenance management system to save time, reduce paper work and enables the professionals to focus on technical aspects rather than on routine paper works.

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APPENDIX

ASSESSMENT OF ROAD MAINTENANCE MANAGEMENT SYSTEM OF ADDIS ABABA CITY ROAD AUTHORITY (AACRA)

This questionnaire is designed to assess the current road maintenance management system of Addis Ababa city road authority(AACRA) .Your responses will be anonymous; data will be combined and analyzed as a whole. Please attempt to answer all the questions and tick one which is appropriate box that best suits your perspective for each statement. Your participation in the study will be greatly appreciated.

Thank you very much for your time and assistance.

PART I Respondent characteristic

Sex of Respondent

A. Male ( ) Female ( )

Age of Respondent

A.20-29 years ( ) B.30-39 years ( ) C.40-49 years ( )

D.50-59 years ( ) E 60 years and above ( )

Highest level of education

A .Postgraduate ( ) B. Degree ( ) C. higher diploma ( )

Work experience

A.0-5 years ( ) B.5-10 years ( ) C.10-15 years ( )

D. above 15 years ( )

PART II Road maintenance management process

How often do you carry out road inventory and condition survey in your organization?

A. Annually ( ) B. Not carrying out ( )

Which method do you use for road inventory and condition survey?

A. Your own method ( )

B. Using formats of ERA ( )

C .Any other format ( )

What difficulties do you face during road inventory and condition survey?	Please thick
In adequate funding	
In adequate transport	
Less man power	
In adequate funding and transport	
Inadequate funding and less man power	
Inadequate funding , transport and man power	
Takes more time	

Is there any particular road maintenance prioritization criteria in your organization?

A .Yes ( ) B. No ( )

What road maintenance prioritization criteria do you use in your office?	Please thick
Your own criteria	
Road fund criteria	
Ministry criteria	
Government influence	

How frequently do you use these factors during road prioritization?				
Factors	Not used	Occasionally	Frequently	More frequently
Technical factor				
Socio-economic factors				
All stake holders priorities				
Governments influence				

How do you carry out assessment of quantities for preparation of maintenance plan?

By filling standard forms from road fund	
Using your own developed forms	
Other methods (specify)…..	

PART III Factors affecting road maintenance management system

Which of the following factor are the most important in road maintenance management in AACRA	NI	LI	A	I	VI
Allocated budget	0	1	2	3	4
Required quality	0	1	2	3	4
Quality of design	0	1	2	3	4
Worker's skill	0	1	2	3	4
Data of inventory and road condition survey	0	1	2	3	4
Data base system	0	1	2	3	4

4.-Very Important (VI) 3.-Important (I) 2-Avarage (A)

1-Less Important (LI) 0-Not Important (NI)

PART IV challenges occur during road maintenance management system?

List of problems	SD	D	A	AE	SA
In adequate funding	0	1	2	3	4
Not have standard manual and guideline	0	1	2	3	4
In adequate training	0	1	2	3	4
Lot of paper works	0	1	2	3	4
Not privatization of road maintenance works	0	1	2	3	4
Traditional data collection system	0	1	2	3	4

4-Strongly Agree (SA) 3-Agree (AE) 2-Avarage (A)

1 - Dis Agree (D) 0- strongly Disagree (SD)

In your view how effective is the road maintenance management being used in your office?	Please thick
Effective	
Not sure	
Ineffective	

PART V approaches to improve road maintenance management system

What should be done to improve road maintenance management system in your office?	SD	D	A	AE	SA
Use of standard methods and methodology	0	10	2	3	4
Use of computerized systems	0	1	2	3	4
Privatization of road maintenance	0	1	2	3	4
More funds	0	1	2	3	4
Central data base system	0	1	2	3	4
Advanced data collection tools	0	1	2	3	4
Improve human resource (by training)	0	1	2	3	4

4 -Strongly Agree (SA) 3- Agree (AE) 2- Average (A)

1- Dis agree (D) 0- Strongly disagree (SD)